DEPARTMENT OF SCIENTIFIC
AND INDUSTRIAL RESEARCH

GEOLOGICAL SURVEY AND MUSEUM

BRITISH REGIONAL GEOLOGY

THE WELSH BORDERLAND

(SECOND EDITION)

by

R. W. POCOCK, D.Sc.,
and
T. H. WHITEHEAD, M.Sc., A.R.C.Sc.

LONDON: HIS MAJESTY'S STATIONERY OFFICE
1948
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THE WELSH BORDERLAND

I. INTRODUCTION

History of Research.—Since the earliest days of the history of the science of geology the Welsh Borderland has attracted the attention of geologists by the great variety and interest of its formations; for in no other area perhaps can the sequence of the Palaeozoic rocks be seen to such advantage and within such a comparatively small district (Fig. 1, p. 2).

The first comprehensive investigation of the rocks of the area was made by Sir Roderick Murchison, who, in 1835, introduced the well-known name 'Silurian' for the series of rocks which he had studied in the land of the old British tribe of the *Silures* (Shropshire, Herefordshire and South Wales); he divided this system into an upper and a lower series.

In the meantime Professor Sedgwick had worked out the succession of the Palaeozoic rocks of North Wales and, in 1835, proposed the name Cambrian for this sequence, adopting Murchison's name Silurian for the overlying rocks in the Berwyn Mountains. It was then found that the lower part of the Silurian of Murchison and the upper part of the Cambrian of Sedgwick were in part equivalent, and in 1879 Professor Lapworth suggested the name 'Ordovician' (from the tribe of the *Ordovices* which inhabited North Wales) for the middle portion of the Cambro-Silurian sequence, the designation of which was in dispute. Lapworth's classification of the older Palaeozoic rocks into Cambrian, Ordovician and Silurian is now generally accepted.

Murchison's great work *The Silurian System*, published in 1839, still remains a fund of information and a basis for the work of investigators in the region and, with his *Siluria* published in 1854 (and four later editions), forms a monument to the knowledge and industry of this pioneer in the science, whose researches embraced not only the older Palaeozoic rocks but also the earlier pre-Cambrian and the later Old Red Sandstone and Carboniferous rocks of the district.

Among other early workers whose well-known names may be mentioned are Aitkin, Lewis, Prestwich, Phillips, Salter, Aveline, Lightbody, Allport, Bonney, Maw, Morton, Callaway and Blake, who have all contributed to the elucidation of the geology of this complex region. We may also refer to W. S. Symonds, who, in his *Records of the Rocks*, 1872, deals in a charming and interesting manner with the geology, natural history and antiquities, and to J. D. La Touche, whose *Handbook to the Geology of Shropshire*, 1884, is a useful guide to the more important localities and contains numerous drawings of typical fossils.

The original maps of the Geological Survey on the scale of 1 in. to a mile were published between the years 1844 and 1855, and there were revisions up to 1873. A number of horizontal sections were also produced on a scale of 6 in. to a mile.

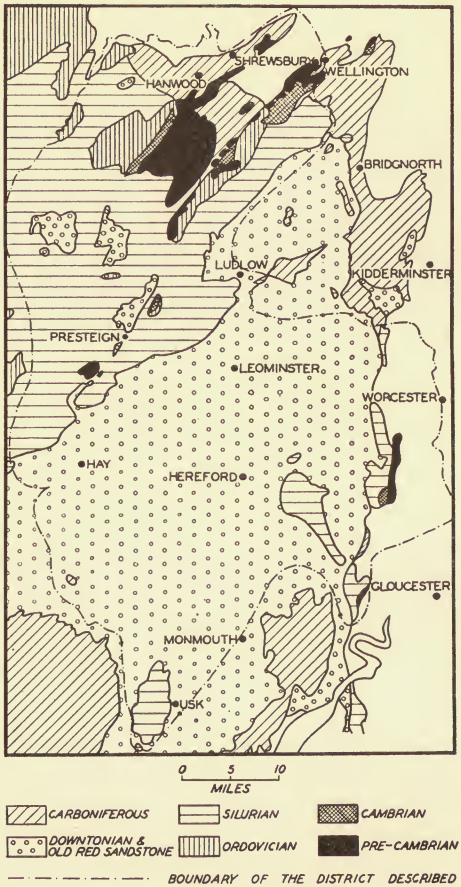


FIG. 1.—*Sketch-map of the Geology of the Area.*

Modern methods of investigation may be said to have been initiated by Charles Lapworth and W. W. Watts, who for many years directed and stimulated the progress of research. The former was the discoverer of the '*Olenellus*' fauna in the Lower Cambrian rocks of Shropshire and did much valuable work on the Ordovician rocks of the Shelve district, while the latter has made important contributions to our knowledge of the geology of the Breidden Hills, the Corndon laccolite, the Long Mountain syncline and other areas.

Important work has also been done by W. S. Boulton on the Uriconian rocks, by E. S. Cobbold, C. J. Stubblefield and O. M. B. Bulman on the Cambrian, by G. L. Elles, E. M. R. Wood, I. L. Slater and W. F. Whittard on the Silurian, and by W. W. King on the Old Red Sandstone.

In the Malverns the work of John Phillips, 1846, Charles Callaway, 1880–1893, and others has been followed up by T. T. Groom, whose studies of this region were published in 1899, 1900 and 1902.

The Old Radnor district was described by E. J. Garwood and E. Goodyear in 1919.

In recent years the Geological Survey has turned its attention once more to this interesting Borderland and primary mapping on the 6-in. scale has been completed in the area covered by the New Series 1-in. map Sheet 152 (Shrewsbury). This sheet was published in 1932 (Solid and Drift editions). In the south-west, parts of the district resurveyed fall within the area covered by New Series Sheets 249 (Newport), 232 (Abergavenny), and 233 (Monmouth).

Physical Features and Drainage.—The main physical features of the Welsh Borderland may best be described from north to south.

The district is bounded on the north by the great plain of North Shropshire, floored by Coal Measures and Triassic rocks which invade the northern slopes and spurs of the old Palaeozoic mass to the south and are largely obscured by a mantle of drift deposits, consisting of boulder-clay and glacial sands and gravels, brought into the district by ice both from the Irish Sea and from the Welsh Mountain area to the west.

The River Severn, descending from the high ground of Wales, enters upon the Shropshire plain a few miles below Welshpool, meanders eastwards along its southern border, cutting, in places, across spurs of the older rocks that project into it, and finally leaves the plain by the narrow gap of the Ironbridge Gorge to flow southwards to the Bristol Channel.

The first important feature met with south of the river is the striking mass of the Breidden (Pl. V B) rising to 1,202 ft., with Moel-y-Golfa, 1,324 ft., the former a remarkable laccolite of dolerite the general structure of which is anticlinal, and the latter an intrusion of andesite.

To the south of the Breidden mass lies the syncline of the Long Mountain composed of Upper Silurian rocks rising to a height of 1,277 ft.

The Shelve district of Ordovician rocks, rising to a culminating point of 1,684 ft. in the great laccolite of dolerite known as the Corndon (Pl. VI), is separated from the Long Mountain syncline by a broad

valley cut in soft Silurian shales and drained by small streams flowing in opposite directions; actually at times from the same pool (Marton Pool) on the low watershed. The Shelve Ordovician area is bounded on the south-east by the impressive ridge of the Stiperstones (Pl. VII), formed of Arenig quartzite; the jagged crags of this resistant rock, piercing the skyline, can be seen from a great distance.

A valley cut in Cambrian shales separates the Shelve Ordovician mass from an area of pre-Cambrian rocks including the plateau of the Longmynd (Pl. I), which is composed of an immense thickness of pre-Cambrian grits, flags and conglomerates with high to vertical dip. This plateau, four to five square miles in area, rises to a maximum height of 1,696 ft. and, though approximately level, slopes gradually to the north and south. Its steep edges are deeply trenched by streams forming the valleys known locally as 'batches' or 'gutters.'

A spur of the Longmyndian rocks extends north-eastwards in Bayston and Sharpstone Hills and, beyond the River Severn, rises again in the outstanding mass of Haughmond Hill.

The Longmynd is flanked on either side by outcrops of pre-Cambrian volcanic rock—the Western and Eastern Uriconian Groups. The Western Uriconian gives rise to the prominent mass of Pontesford Hill (Pl. IV) and smaller igneous areas to the south-west. The Eastern Uriconian is developed, along the great Church Stretton Fault, in the remarkable range of hog-backed hills (Pl. VA), Ragleth, Caradoc, the Lawley and, in continuation of their line, those of the Wrekin (Pl. III), Ercall and Lilleshall to the north of the River Severn.

Ordovician and Silurian rocks form a succession of ridges and valleys south-east of, and parallel to, the Eastern Uriconian range. The lowest beds of the Ordovician are the grits which give rise to the scarp of Hoar Edge. The Wenlock Limestone forms the scarp of Wenlock Edge, about sixteen miles long, and the Aymestry Limestone the parallel scarp of View Edge.

To the south-east of the Aymestry Limestone ridge lies a triangular plateau formed of the higher beds of the Silurian system and the overlying Old Red Sandstone. Two table-topped masses rise from this plateau, the Brown Clee, 1,792 ft., and Titterstone Clee, 1,749 ft. (*see* British Regional Geology, *Central England*). These are outlying relics of Coal Measures which have been protected from denudation by thick coverings of contemporaneous dolerite or basalt.

The southern slopes of the Longmynd and Shelve country are drained by the Rivers Onny and Camlad, which also drain the northern slopes of the plateau of Clun Forest—a synclinal basin of Upper Silurian rocks rising to a height of 1,796 ft. in Beacon Hill.

The central part of the Clun Forest district is drained by the River Teme, which, flowing by Downton Castle, Ludlow and Tenbury, forms the southern boundary of the tracts of high ground mentioned above, most of which lie within the county of Shropshire.

Ludlow (Pl. IX) is situated on the north-eastern rim of a faulted anticline of Silurian rocks in the core of which lies the Vale of Wigmore

on the Wenlock Shale. In this area the wooded ridges formed by the Wenlock and Aymestry limestones are well-marked scenic features.

South of Ludlow, around Leominster, Hereford and Monmouth, an extensive area, mainly of Downtonian and Old Red Sandstone rocks, is dissected by the rivers Teme and Wye and their tributaries. On the west of this area the continuation south-westwards of the Church Stretton line of faulting brings to the surface the interesting area of Old Radnor, where Silurian strata can be seen resting unconformably on pre-Cambrian (Longmyndian) rocks (Pl. VIII A). Here also are the igneous masses of Hanter, Worsel Wood and Stanner (Pl. X A) the age of which is probably pre-Cambrian. Farther south the most striking feature of the landscape is the great escarpment of the Black Mountain (Pl. X B), composed of Old Red Sandstone, rising well above 2,000 ft.

The district is bounded on the east by the uprise of the Silurian, Cambrian and pre-Cambrian rocks of the Malvern range (Pl. II), beyond which lies the Triassic plain of Worcester. The summit of North Hill, Malvern, 1,307 ft., is the highest point of the range.

The Silurian inlier of May Hill lies on the continuation southward of the Malvern axis and, with the Silurian district of Ledbury and the Silurian inlier of Woolhope, shows the same type of scenery (due to alternation of wooded limestone scarps with valleys cut in the intervening soft shales) as that in the Ludlow and Wenlock country.

The Old Red Sandstone tract continues southward between Abergavenny and Monmouth to the Bristol Channel, interrupted only by the uprise of the Silurian inlier of Usk and flanked by the Carboniferous Limestone outcrops of the South Wales syncline on the west and of the Forest of Dean syncline on the east.

Geological History.—Throughout the geological history of this district there have been constant change and instability, as evidenced by the numerous breaks in the sedimentary sequence and the number of marked unconformities.

The oldest rocks are of pre-Cambrian age. In Shropshire they are represented by the schists of Rushton, the gneissic rocks of Primrose Hill and the Uriconian Volcanic Series; also by the Longmyndian sediments, which comprise an immense thickness, estimated at 27,000 ft., of shales, flags, grits and conglomerates produced by regular and even deposition. In the Malvern district the pre-Cambrian rocks consist of gneisses and schists, termed the Malvernian Group, and a volcanic series, the Warren House Group, which is comparable with the Uriconian of Shropshire.

A great interval of time appears to have elapsed between the formation of these pre-Cambrian rocks and the beginning of the Cambrian period, for the relation of the lowest Cambrian rocks to the Uriconian Volcanic Series is one of strong unconformity.

The Cambrian period was heralded by a great transgression of the sea. The pre-Cambrian formations had been strongly folded and denuded to an almost level surface before the oldest Cambrian rocks were laid down. The type of sedimentation met with in the Lower

Cambrian suggests that the sea was then shallow and subject to current and wave action. Earth-movements took place during Cambrian time, as proved by unconformities within the system, while the presence of a great thickness of uniformly fine sediment in the Upper Cambrian seems to indicate a progressive lowering of the sea floor.

At the close of the Cambrian period a shallowing of the sea took place not only by the accumulation of sediment but also by an elevation of the sea floor, which seems to have brought much of Shropshire and the Midlands above sea-level, where the Cambrian and pre-Cambrian rocks suffered erosion. This episode may be regarded as the precursor of the great 'Caledonian' mountain-building movements which reached their maximum in post-Silurian time.

At the beginning of Ordovician time progressive subsidence again began in this district, and the basal Stiperstones quartzite represents the sandy deposit of a shallow sea which was subsequently followed by the grits, flags and shales of the lower division of the Ordovician. At this time also there was a great outburst of volcanic activity, both submarine and subaerial, producing the tuffs and lavas of the Shelve district. Further subsidence carried the sea into the eastern parts of Shropshire and the Upper Ordovician (Caradocian) grits, sandstones and limestones were laid down unconformably on Cambrian and pre-Cambrian rocks, while deposition of shales and ashes proceeded without break in the western areas.

Extensive earth-movements at the beginning of Silurian times resulted in a considerable tract of land appearing over Shropshire and the Midlands. This was subjected to denudation while Lower Llandovery deposits were forming on the sea floor to the west. When subsidence again brought the sea over this land Upper Llandovery sediments were laid down unconformably upon all the subdivisions of the Ordovician and on the Cambrian and pre-Cambrian rocks of Shropshire and the Malvern district.

Throughout Upper Llandovery, Wenlock and Ludlow times deposition appears to have been continuous over the Welsh Borders in waters of shallow or moderate depth from which rose islands of the older rocks such as the Longmynd-Shelve area upon the flanks of which the sandy and conglomeratic basal Upper Llandovery Beds were deposited, and the Old Radnor ridge against which the reef-facies of the Woolhope Limestone was formed. The shallowness of the sea during the formation of the Wenlock Limestone is indicated by the presence of reef knolls formed of masses of coral growing upward to the surface. Deeper water lay to the north-west of the Shelve area and over Wales, the shallow-water shelly and coral facies of the Silurian giving place to a graptolitic facies in that direction.

The close of Silurian times was marked by the great earth-movements, accompanied by volcanic episodes, of the 'Caledonian' mountain-building epoch. Within the Welsh Border district, however, sedimentation went on continuously from the Silurian to the end of Lower Old Red Sandstone times. The conditions of sedimentation changed considerably at the end of the period of deposition of the Ludlow Beds. The shelly limestones and shales of definitely marine

type gave place to the red marls and sandstones, with cornstone bands, of the Downtonian and Lower Old Red Sandstone, which appear to have been deposited under shallow-water or deltaic conditions at no great distance from the land areas which emerged as the result of the earth-movements mentioned above. From these rising continental masses vast quantities of mud and sand were swept down and spread out in the shallow waters, where continuous down-warping kept pace with sedimentation.

Upward movement accompanied by some folding and followed by denudation took place at the end of Lower Old Red Sandstone time in the Welsh Border district, and no deposits of Middle Old Red age appear to have been formed. This was followed by depression resulting in the deposition of the Upper Old Red Sandstones in unconformable relation to various horizons of the Lower Old Red.

At the close of the Old Red Sandstone period a great part of the continental areas had been reduced to sea-level, and with further subsidence a fresh invasion of the sea took place over most of the British area.

In this sea the marine deposits of the Lower Carboniferous were formed, consisting in large part of limestones and shales. There were occasional episodes of volcanic activity at this period.

At the close of Lower Carboniferous time much terrigenous material was swept into the district, converting it into a delta swamp—a great area of swampy peat-morasses formed practically at sea-level and covered with the dense vegetation which eventually became coal. Intermittent subsidence gave rise to thick deposits of sand and mud, forming the measures between the successive layers of coal, or occasionally to incursions of the sea resulting in ' Marine Bands ' which are found at intervals in the Coal Measures.

Important earth-movements, foreshadowing greater movements to come, took place in the district before the deposition of the Upper Coal Measures, and were accompanied by intrusions and extrusions of basic lava. The Upper Coal Measures rest unconformably on the pre-Carboniferous rocks in the Shrewsbury Coalfield and on the folded older Coal Measures of the Coalbrookdale and Wyre Forest areas on the east of the district.

With the close of the Carboniferous period the great ' Hercynian ' crustal movements set in from the south and, reflected eastwards from the resistant mass of the old north-east and south-west pre-Cambrian axis of Old Radnor and the Longmynd, piled up the north and south tectonic folds of the Malverns and, in the intermediate area, formed the north-west and south-east principal fold of the Woolhope anticline, the syncline of the Forest of Dean and the Usk anticline.

Towards the north, where the axis of the Malvern fold approaches the old Longmyndian mass which formed a rigid block, the former slews round north-eastwards in the Abberley Hills. Still farther north the pressure apparently produced a succession of folds and faults trending east-north-eastwards, as in the Ludlow and Clee Hill district. It is probable that much of the movement along these faults has been

lateral, giving relief to the northward pressure against the Longmynd barrier by movement towards the north-east. The uprise of the so-called Mercian Highlands at this time was followed by the arid continental conditions of the Trias with its widespread desert deposits including wind-blown sand and gypseous marls.

The history of the rock formations of the district ends with the Trias, all later stratified deposits having been removed by denudation; and there only remain to be mentioned the deposits of the Glacial and post-Glacial periods.

The Irish Sea ice sheet advanced over the North Shropshire plain and pressed against the northern side of the old Palaeozoic mass of South Shropshire, while the Welsh ice descended from the hills down the Severn valley and farther south into the valleys of the Teme and Wye. A discussion of this episode is given in the sequel.

On the retreat of the ice tumultuous deposits of sand, gravel and boulder-clay were left behind, masking the solid rocks over large areas. The rivers were, in many cases, now obliged to find new channels, and the present system of drainage is to a large extent a legacy of the Great Ice Age.

The formations represented in the district are summarized in the following table with estimates of thickness where possible.

GEOLOGICAL SEQUENCE

Recent:—
Alluvium, river gravels, hill and valley peat, tufa, etc.

Pleistocene:—
Boulder-clay, Glacial sands and gravels, Lacustrine deposits.

Triassic:—

Keuper Marl	near Malverns 700 ft.; maximum in south 1,700ft.
Lower Keuper Sandstone	up to about 400 ft.
Upper Mottled Sandstone	over 200 ft.
Bunter Pebble Beds	absent in south; in north 150 ft.
Lower Mottled Sandstone	absent in south; in north about 600 ft.

Carboniferous:—
Upper Coal Measures (or Permian): Haffield Breccia.
Upper Coal Measures (Shrewsbury Coalfields):

Erbistock Group	Alberbury Breccia	250 ft.
	Keele Beds	150–1,500 ft.
Coed-yr-Allt Group		400 ft.
Ruabon Marl		0–22 ft.

also Upper Coal Measures of Abberley Hills and Newent Coalfield.

Old Red Sandstone:—

Upper Old Red Sandstone: Quartz Conglomerate Group of Black Mountains	400–500 ft.
Lower Old Red Sandstone: Brownstones of the Black Mountains, Dittonian of Shropshire and Herefordshire	about 1,300 ft.

Silurian:—

Downtonian: red marls and sandstones	about 2,000 ft.
Upper Ludlow Shales	250–700 ft.
Aymestry Limestone	100–400 ft.
Lower Ludlow Shales	600–1,500 ft.
Wenlock Limestone	100–250 ft.
Wenlock Shale	1,000–2,000 ft.
Woolhope Limestone	10–150 ft.
Upper Llandovery: sandstones and shales	100–1,000 ft.

Ordovician:—

CARADOC AREA

Caradoc Series .. .. minimum 2,000 ft.
- Acton Scott Group:
  - Upper *Trinucleus* Shales
  - Acton Scott Limestone
- Longville Group:
  - Lower *Trinucleus* Shales
  - Longville Flags
- Chatwall Group:
  - *Alternata* Limestone
  - Chatwall or Soudley Sandstone
  - *Glyptocrinus* Flags
- Harnage Group:
  - Harnage Shales
- Hoar Edge Group:
  - Hoar Edge Grit and Limestone

PONTESFORD AREA

Caradoc Series .. .. minimum 1,000 ft.
- Pontesford (*Mesograptus*) Shales

BREIDDEN HILLS

Caradoc Series .. .. minimum 1,500 ft.
- Upper Shales
- Upper Volcanic Group
- Middle Shales
- Lower Volcanic Group
- Lower Shales

STIPERSTONES, SHELVE AND CHIRBURY AREA

Caradoc Series
- Marrington Stage .. .. minimum 1,000 ft.
  - Whittery Shales
- Hagley Stage .. .. 800 ft.
  - Whittery Volcanic Group
  - Hagley Shales
  - Hagley Volcanic Group
- Aldress Stage .. .. 900 ft.
  - Aldress Shales
  - Spy Wood Grit
- Rorrington Stage .. .. 400 ft.
  - Rorrington Flags and Shales

Llandeilo Series
- Meadowtown Stage .. .. 800 ft.
  - Meadowtown Flags and Limestone

Llanvirn Series
- Betton Stage .. .. 200 ft.
  - Betton Shales
- Weston Stage .. .. 500 ft.
  - Upper Weston Grit
  - Weston Shales
  - Lower Weston Grit
- Stapeley Stage .. .. 900 ft.
  - Stapeley Shales
  - Stapeley Volcanic Group
- Hope Stage .. .. 800 ft.
  - Hope Shales

Arenig Series
Mytton Stage .. .. minimum 2,000 ft.
Mytton Flags and Shales
Stiperstones Quartzite

Cambrian:—
Tremadoc Series .. .. 3,000–4,000 ft.
Shineton Shales and Bronsil Shales
Lingula Flag Series
Grey or *Orusia* Shales and Black or Whiteleaved Oak Shales
Paradoxides Series .. .. 300–500 ft.
Upper Comley Sandstones and Upper Hollybush Sandstone
Olenellus Series .. .. 500 ft.
Lower Comley Limestone and Sandstones and Lower Hollybush Sandstone
Wrekin and Malvern Quartzite .. .. 50–150 ft.

Pre-Cambrian (divisions not necessarily in order of age):—
Longmyndian:
Western Longmyndian or Wentnor Series .. .. about 17,000 ft.
Eastern Longmyndian or Stretton Series .. .. about 10,000 ft.
Uriconian:
Eastern Uriconian lavas and tuffs
Western Uriconian lavas and tuffs
Warren House Group of Malvern
Primrose Hill gneiss and schist
Rushton Schist
Malvernian:
Gneisses and schists

Intrusive igneous rocks in the Old Red Sandstone, Downtonian, Ordovician, Cambrian and pre-Cambrian.

II. PRE-CAMBRIAN

SOME OF THE most ancient rocks of England and Wales appear at the surface in the Welsh Border district (Fig. 2, below). Being, for the most part, hard and resistant to weathering, these ancient rocks tend to form hills, and such well-known eminences as the Wrekin,

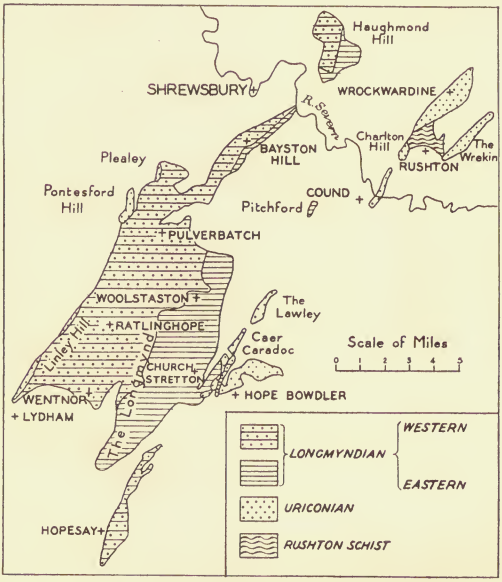


FIG. 2.—*Distribution of Pre-Cambrian Formations in Shropshire.*

Caer Caradoc and the Longmynd, in Shropshire, and the Malvern Hills, are formed of them.

Since these rocks have been subjected to the vicissitudes of a long period of time, they are all more or less altered; some so much that their original characters are almost obliterated. In most cases, however, they are not so changed that their mode of origin cannot readily be inferred.

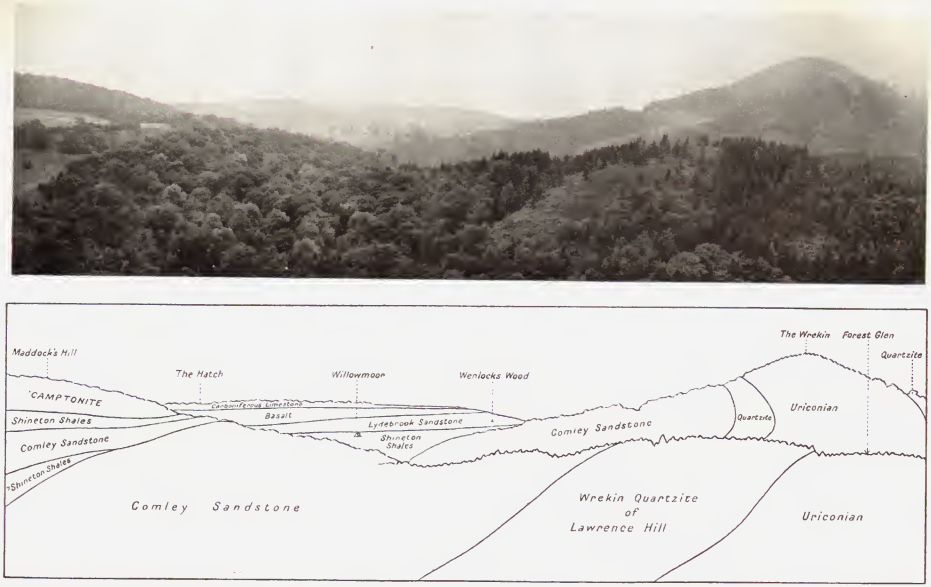
Though some of these ancient rocks contain structures that seem to indicate the presence of living creatures at the time of their formation, most of them are devoid of any trace of fossils. They cannot, therefore, be subdivided, or correlated from place to place, by means of fossils, as is done in the Cambrian and later systems. Instead, a grouping based solely on lithological characters has to be adopted. Moreover, since the rocks have been considerably disturbed, and their original relations to one another altered or rendered obscure, the relative age of the groups is, in some cases, in doubt. That they are older than the Cambrian System is, in most cases, shown by the fact that the rocks of that system rest upon them, and, in places, contain fragments of them in their basement beds. In some cases, however, such direct evidence is not available, and the pre-Cambrian age is inferred on other grounds.

All the principal classes of rocks are represented in these pre-Cambrian groups. Some of them are sedimentary rocks, composed of the debris of pre-existing strata deposited in water, as mud, sand or gravel, in more or less horizontal layers, and subsequently consolidated and disturbed. Such rocks are represented by the Longmyndian group, named after the Longmynd, near Church Stretton, and by similar rocks in Radnorshire and Gloucestershire.

Others of the pre-Cambrian rocks are volcanic in origin. These include the remains of ancient lavas, and of tuffs and breccias, that is, rocks consisting of material ejected as dust or fragments from a volcanic vent and deposited on land or in water, either directly or after having been washed down the slopes of a volcano. Such rocks are represented by the Uriconian group of Shropshire; named by Charles Callaway after the Roman city of Uriconium, the name of which was probably derived from that of the Wrekin which is mainly formed of these volcanic rocks. Caer Caradoc and other hills near Church Stretton, and Pontesford Hill near Pontesbury, are also formed of Uriconian rocks, and there are similar rocks in the Malvern Hills.

Rocks that, since their formation, have been subjected to processes whereby structures or minerals (or both) not originally present have been formed, are known as metamorphic rocks. Before metamorphism many of these were of igneous origin, that is they were formed as injections of molten matter into pre-existing rocks amongst which they cooled and crystallized. Others were of sedimentary origin. Metamorphic rocks are represented by the Malvernian group of the Malvern Hills, and also by the Rushton Schists and certain rocks of the Wrekin in Shropshire.

In addition to those already mentioned, igneous rocks occur amongst those of the other types, into which they were intruded in a molten state. Some of these, chiefly pink or light-coloured rocks rich in silica (acid rocks), show a relationship to the volcanic rocks, with which they are probably nearly contemporaneous. Others, heavy, dark-coloured rocks poor in silica (basic rocks), are of considerably later date than those into which they were intruded, and in some cases are post-Cambrian in age.



VIEW LOOKING SOUTHWARD FROM THE ERCALL; WITH DIAGRAM SHOWING THE RELATION OF THE PRINCIPAL ROCK GROUPS TO THE MAIN FEATURES OF THE LANDSCAPE

PONTESFORD HILL AND THE WESTERN LONGMYNDIAN HILLS FROM THE SOUTH NEAR GATTEN LODGE

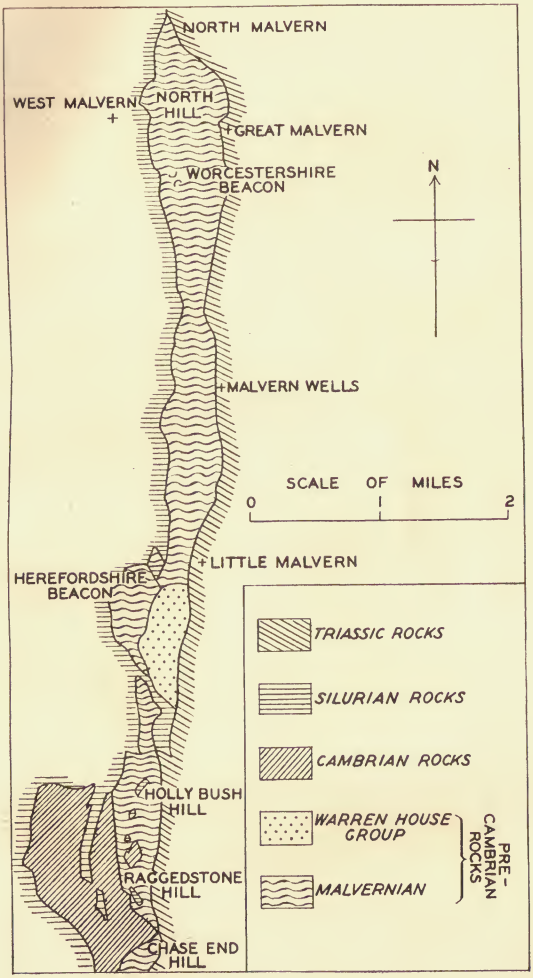


FIG. 3.—*Distribution of Pre-Cambrian Rocks in the Malvern Hills.*
(After T. T. Groom.)

Of the groups above referred to the Malvernian is the most ancient and is perhaps comparable in age with some of the metamorphic rocks of Anglesey and Scotland. The Rushton Schists may be of similar age; but, on the other hand, they are possibly the result of the alteration of one of the later pre-Cambrian groups. The Uriconian rocks seem to be older than at least part of the Longmyndian group, but the relative ages of these two groups is still a matter of uncertainty.

PRE-CAMBRIAN ROCKS OF THE MALVERN HILLS

THE MALVERNIAN GROUP

These, the most ancient rocks of the Welsh Border district, occupy the central axis of the Malvern range (Fig. 3, p. 13). They consist very largely of gneisses, *i.e.* rocks in which intense pressure has produced an irregular layered arrangement or foliation. Originally these seem to have been igneous rocks of medium or high silica percentage, such as diorite, syenite or hornblende-granite; or, in some cases, ' hybrid ' rocks, such as might result from the mixture of granite and gabbro. Rocks of these types occur, indeed, in an unfoliated condition, particularly at the northern end of the chain, on North Hill and the Worcestershire Beacon.

A considerable portion of the railway tunnel near the Wych (Fig. 4, p. 15) was driven through altered diorite (epidiorite), though the rocks on the surface, above the tunnel, are chiefly quartz-mica-schists. In these schists the foliation is more pronounced, so that the rock tends to split into irregular plates.

On the Herefordshire Beacon the rocks are chiefly hornblende- and mica-gneisses, though, at the northern end, a basalt has been recognized. Swinyard Hill, again, shows mica-gneiss, with diorite, more or less altered, and hornblende-granite. On Midsummer Hill and Hollybush Hill both gneisses and schists occur; whilst schists prevail on the Raggedstone Hill, where they include a brecciated quartzite. This last is probably an altered sediment, and so, perhaps, are some of the schists. Chase End Hill, at the southern end of the chain, is formed mainly of hornblende-gneiss.

In various parts of the hills the rocks are invaded by veins of pegmatite (quartz-felspar rock; *see* Pl. II B). Such veins may be well seen in the Gullet Quarry, near Hollybush Hill. Basic intrusions (dolerite, etc.) also occur, and good examples may be seen at the Dingle Quarry, West Malvern, at the Tank Quarry in the North Hill and at the Gullet Quarry.

THE WARREN HOUSE GROUP

This is a group of volcanic rocks much resembling the Uriconian rocks of Shropshire, with which it may probably be correlated. It crops out on Hangmans Hill, Broad Down and Tinker's Hill, to the east and south-east of the Herefordshire Beacon (Figs. 5 and 6, p. 16). It includes lavas rich in silica (rhyolites), others poor in silica (spilites), and tuffs, together with dolerites that are probably intrusive. The

FIG. 4.—*Section along the line of the Malvern Tunnel* (T. Robertson).
(On the scale of about 6 in. to 1 mile.)
(Reproduced from 'Summary of Progress' for 1925, *Mem. Geol. Surv.*, 1926, Fig. 18, p. 166.)

dip seems to be eastward, and these rocks appear to lie unconformably on the Malvernian group, for beneath them the gneisses of the latter are in a weathered condition. The Warren House rocks are considered to be pre-Cambrian partly on account of their resemblance to the Uriconian group of Shropshire and partly because rolled

pebbles of very similar rocks occur in the Malvern Quartzite, at the base of the Cambrian strata.

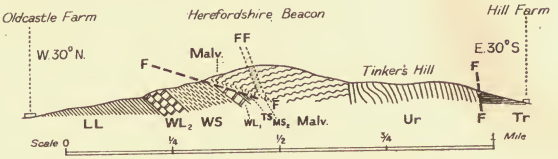


FIG. 5.—*Section across the Herefordshire Beacon and Tinker's Hill.*

(After T. T. Groom.)

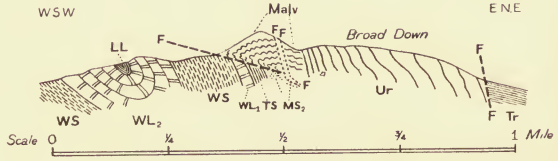


FIG. 6.—*Section across the Herefordshire Beacon and Broad Down.*

(After T. T. Groom.)

Tr = Trias.
LL = Lower Ludlow Shales.
WL_2 = Wenlock Limestone.
WS = Wenlock Shale.
WL_1 = Woolhope Limestone.
TS = Tarannon Shale.
MS_2 = Upper part of May Hill Sandstone.
Ur = Uriconian.
Malv. = Malvernian.
FF = Faults

URICONIAN ROCKS OF SHROPSHIRE

These rocks are divisible into two sub-groups, the Eastern and Western Uriconian, that crop out, respectively, to east and to west of the Longmynd and its northward prolongations. Each consists of volcanic rocks. These include lavas (both acid and basic), in most cases originally glassy. Many of the acid lavas (rhyolites) show banding due to a streaking out of the semi-viscous material during flow. Some of them exhibit those spheroidal nodules that result from a radial growth of crystalline fibres of quartz or felspar about a centre, this growth being part of the process of crystallization from an original glassy condition. With the lavas are tuffs, formed of crystals, glass or rock-fragments, conglomerates and breccias made up mainly of volcanic material. There are, also, intrusions of light-coloured acid igneous rocks (felsites and granophyres) and of dark heavy basic rocks (basalts and dolerites).

THE EASTERN URICONIAN ROCKS

These are typically developed in the Wrekin range, which consists of the Ercall at the north, Lawrence Hill, the Wrekin itself, and

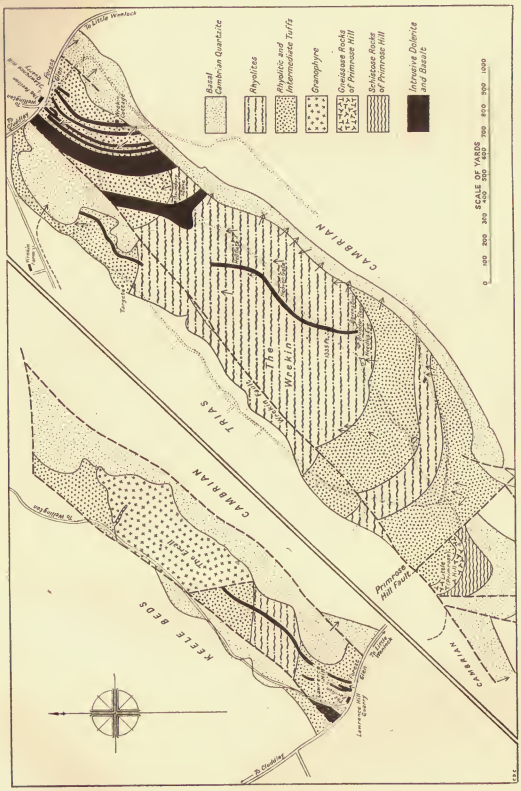


FIG. 7.—*Map of the Uriconian Rocks of the Wrekin Range.*

Primrose, or Little, Hill at the South. The range (Fig. 7, above) shows a succession of volcanic rocks, the general dip being north-eastward. The Uriconian rocks are overlain unconformably by the basal quartzite of the Cambrian System.

At the north end of the Ercall are found alternations of tuffs and

lavas, mainly rhyolitic. Some of the tuffs show, under the microscope, glass-fragments of characteristic shape, exactly similar to those found in tuffs of recent origin. Occupying the central part of the hill is a granophyre, a rock that consists mainly of a rather coarse crystalline intergrowth of quartz and felspar. This seems to be intruded into the volcanic rocks, and in one place can be seen apparently enveloping part of them (Fig. 8, below). To the south of the granophyre more tuffs crop out, which are followed by a group of rhyolite lavas in the glen between the Ercall and Lawrence Hill. These include nodular and beautifully flow-banded examples of rhyolite, well seen in a crag on the north side of the glen.

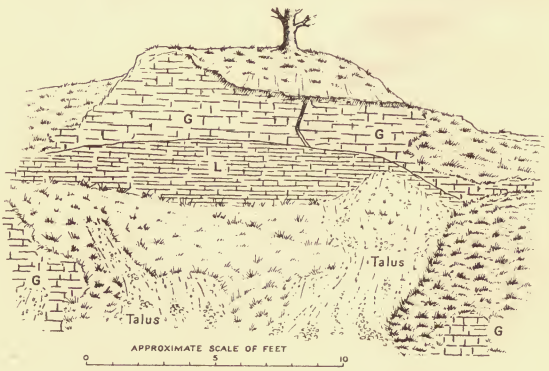


FIG. 8.—*Section on the Ercall showing the junction of granophyre* (G) *and Uriconian lava* (L).

The great quarry in the Forest Glen, between Lawrence Hill and the Wrekin, shows a fine section of tuffs and lavas, including a bed of tuff with rounded boulders of banded rhyolite. The highest part of the Wrekin is occupied by another group of rhyolite lavas, of which banded examples can be seen in the crags near the summit. In the south-west slope tuffs, breccias, and lavas of somewhat basic composition crop out in two bands, separated by a band of predominantly rhyolitic rocks.

On Little, or Primrose, Hill there occur gneissose and schistose rocks bearing the minerals microcline, mica, actinolite and chlorite. These rocks have been compared with the foliated rocks of the Malverns. They are associated with felsitic or granophyric intrusions similar to that of the Ercall, and may have been formed by the injection of these materials into normal Uriconian tuffs.

Intrusions of basalt and dolerite occur cutting across the bedding of the volcanic rocks. Such basic dykes are well seen in the Forest

Glen and on the northern slopes of the Wrekin. These intrusions are of olivine-dolerite type, though in some cases the mineral olivine is not present. None of them has been observed to enter the Cambrian rocks.

Other typical areas of Eastern Uriconian rocks are those of Wrockwardine and Charlton Hill. At Overley Hill (Lea Rock), in the former area, very beautiful spherulitic and banded rhyolites may be seen. The rocks on Charlton Hill include a conglomerate that contains pebbles of rock similar to the granophyre of the Ercall, from which circumstance Charles Callaway concluded that the Uriconian rocks were younger than the Ercall rock. As already mentioned, the Ercall granophyre seems undoubtedly intrusive into the Uriconian rocks of that hill, and therefore later in date. The pebbles in the Charlton Hill conglomerate may have been derived from an earlier granophyric mass, or, possibly, the Charlton Hill Uriconian rocks were formed somewhat later than those of the Ercall.

Uriconian rocks, including types similar to those already mentioned, are found on the Lawley, Caer Caradoc, Ragleth Hill and other hills near Church Stretton and Cardington; but they are known in less detail in most of those localities.

THE RUSHTON SCHISTS

The schists of Rushton, near Uppington, discovered by Callaway, may possibly represent part of the Uriconian or even Longmyndian rocks in a highly altered condition; but, as already mentioned, they may belong to a more ancient group. They are overlain by the Cambrian Quartzite, but their relation to the normal Uriconian rocks is everywhere concealed. They consist of quartz-mica-schists bearing garnet and, generally, much epidote. They are intruded by basic dykes, which also are altered, and by later felsite dykes similar to those in the Uriconian rocks.

THE WESTERN URICONIAN ROCKS

These rocks crop out at intervals along a line from Plealey (two miles south-west of Great Hanwood) to a little north of Lydham. At Plealey lens-shaped outcrops of felsite are found amongst rocks of Longmyndian aspect.

At the Lyd Hole, in the Habberley or Pontesford Brook, near Pontesford, an alternation of basic and acid tuffs and lavas dips to the south-east at a high angle. These are apparently overlain by Longmyndian grits; but there are signs of faulting at the junction.

Pontesford and Earl's Hills (Fig. 9, p. 20) are formed of a succession of volcanic rocks intruded by large masses of olivine-dolerite. The volcanic rocks begin, at the north end, with a group of rhyolites of which some have a striking nodular structure. Next come some rather acid tuffs and a small outcrop of basalt lava. One of the dolerite intrusions occupies a large part of Pontesford Hill; but south and west of it there appears a group of basic tuffs. These include

coarse breccias with angular fragments of lava, and also tuffs consisting largely of altered glass of chemical composition similar to that of basalt (palagonite tuffs). The highest part of Earl's Hill is formed

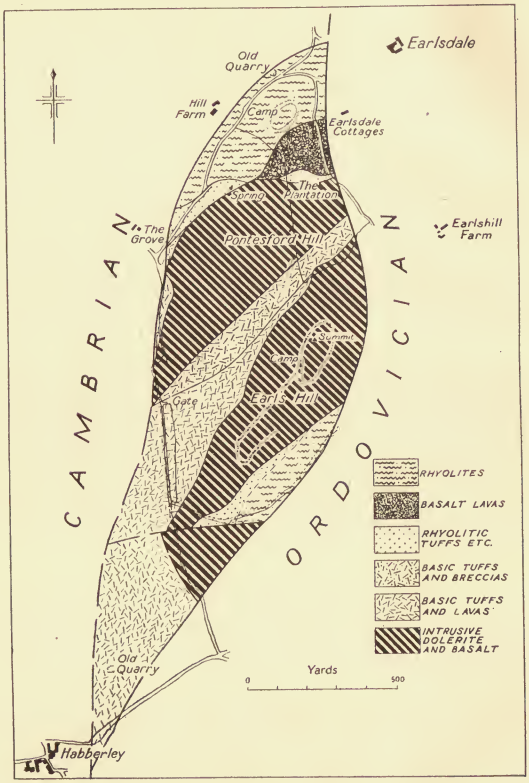


FIG. 9.—*Map of the Uriconian Rocks of Pontesford and Earl's Hills.*

of intrusive dolerite; but on the western side are found basic tuffs, some with palagonite, others very fine-grained and flinty in appearance (halleflintas), with flows of basaltic lava. Similar rocks crop out in a small ridge north-east of Habberley village. On the south-east side

of Earl's Hill another group of acid rocks appears. These include rhyolitic breccias and tuffs, and rhyolites, some of the last being spherulitic.

Near the Knolls, two and a half miles west of Ratlinghope, the volcanic rocks again crop out (Fig. 10, p. 22). These consist of rhyolites followed, eastward, by an alternation of coarse and fine tuffs of intermediate or basic composition. The beds dip westward and are in contact, on the east, with Longmyndian grit and conglomerate. On the west they are faulted against Upper Cambrian shales. This outcrop of volcanic rocks can be followed, nearly continuously, south-westward for about two miles, to Chittol Wood, where they are intruded by basalt, and where a granophyre, probably also intrusive, is present. Similar rocks, together with tuffaceous shales and many basic intrusions, crop out in Linley Big Wood, north of Lydham.

THE IGNEOUS ROCKS OF HANTER AND STANNER

The hills of Stanner Rocks, Worsel Wood and Hanter Hill (Pl. X A), near Old Radnor, are composed of basic igneous rocks ranging from gabbro to dolerite, with dykes of acid rocks such as felsite and granophyre. Some of the latter closely resemble the granophyres associated with the Uriconian rocks north of Lydham; and the Hanter and Stanner igneous rocks were, in fact, referred to the Uriconian by Charles Callaway. It has been claimed that they are intrusive into Silurian shales; but later work has not substantiated this view. These recent studies have emphasized the resemblance of the igneous rocks to some of the pre-Cambrian intrusions of Shropshire and have shown that very similar rock-types occur as pebbles in the Longmyndian conglomerates of the Old Radnor area. There is thus a strong presumption that the Hanter and Stanner rocks are pre-Cambrian in age.

THE LONGMYNDIAN ROCKS

These rocks are divisible into two series: (*a*) the Stretton 'Series' or Eastern Longmyndian, and (*b*) the Wentnor 'Series' or Western Longmyndian.

THE STRETTON 'SERIES'

This 'series' consists largely of flags and shales. The beds may be well seen along the Cardingmill Valley and the Lightspout Hollow, near Church Stretton. Here the dip is westward, and the following subdivisions, established by Charles Lapworth, succeed one another from east to west (Fig. 10, p. 22).

1. *The Stretton Shales.*—These are dark blue or green shales with calcareous nodules. They were subdivided by Lapworth into the Watling Shales, on the east side of the Church Stretton Valley, and the Brockhurst Shales, on the west side. The outcrops of these subdivisions are separated by the Stretton fault and a down-faulted strip of Silurian rocks. The Watling Shales pass down into grits (the Helmeth Grits) which contain fragments of rock of types that can be matched in the Uriconian. The Brockhurst Shales can be seen at the entrance to the Cardingmill Valley.

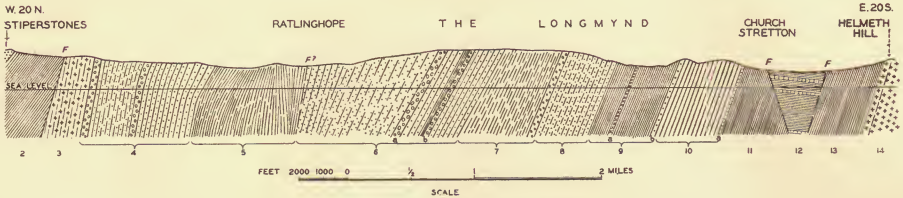


FIG. 10.—*Section from the Stiperstones, across the Longmynd, to Helmeth Hill.*

1. Stiperstones Quartzite; 2. Cambrian (Shineton) Shales; 3. Western Uriconian; 4. Oakswood Group; 5. Bridges Group; 6. Bayston Group, (*a*) Stanbatch Conglomerate, (*b*) Darnford Conglomerate; 7. Portway Group; 8. Lightspout Group; 9. Synalds Group, (*a*) Batch Volcanics, (*b*) Cardingmill Grits; 10. Burway Group, (*a*) Buxton Rock; 11. Brockhurst Shales; 12. Silurian; 13. Watling Shales; 14. Eastern Uriconian.

(Eastern part based upon the work of C. Lapworth and E. S. Cobbold.)

2. *The Burway Group.*—This consists of grey-green flagstones, and begins with a hard, fine-grained siliceous tuff, the 'Buxton Rock,' which can be seen in a small quarry just within the Cardingmill Valley and also in the Buxton quarries at All Stretton. The green flags and shales east of Eleanor's Bower, on Haughmond Hill, probably belong to the Burway Group.

3. *The Synalds Group.*—This is made up mainly of purple shales, but begins with some micaceous sandstones (the Cardingmill Grits) that crop out at the Cardingmill. Within this group there occur thin but fairly persistent bands of volcanic tuffs (the 'Batch Volcanics' of E. S. Cobbold).

4. *The Lightspout Group.*—This group consists largely of hard, gritty rocks that include the white-weathering beds of Haddon Hill, and the massive grey grit that gives rise to the Lightspout waterfall.

5. *The Portway Group.*—This consists of purple and green shales and flags, with some beds of grit and conglomerate.

Some of the beds of the Stretton 'Series,' notably the Burway and Synalds groups, show markings that have been considered to be of organic origin. Some of these have been interpreted as worm-tracks and burrows ('*arenicolites*' and '*histioderma*'). Other markings are possibly rain-prints, and there also occur ripple-like structures that may, in some cases, be due to current or wave action at the time of deposition. In most cases, however, these 'ripples' are probably due to the effects of pressure and shearing upon the rocks long after they were deposited.

THE WENTNOR 'SERIES'

The Wentnor 'Series' consists mainly of coarse grits and conglomerates, with subordinate shales and sandstones. As pointed out by Charles Lapworth, the rocks of this group somewhat resemble the Torridon Sandstone of Scotland, with which they are, perhaps, contemporaneous.

The grits and conglomerates of the 'Series' contain many fragments of volcanic rocks that closely resemble those of the Uriconian, and also fragments of felspar-crystals of the kinds found as original constituents in the latter. In the conglomerates a small percentage of the pebbles consists of soda-granite, or similar rocks, and fragments of such rocks are rather common in the grits of certain localities. The granite mass from which these were derived is unknown.

The Wentnor 'Series' may be divided into three groups, as follows :—

1. *The Bayston Group.*—This consists of purple grits and conglomerates which crop out on Haughmond Hill, at Bayston Hill and on the summit of the Longmynd, where they follow upon the Portway Group. The conglomerates occur in three persistent belts, named by Lapworth, in order from east to west, the Haughmond, Darnford and Stanbatch Conglomerates (Fig. 10, p. 22). The Haughmond Conglomerate contains a very high proportion of pebbles of volcanic

rock. Unlike the other two, it appears not to persist as far south as the Longmynd.

2. *The Bridges Group.*—This consists of dark purple shales and fine-grained sandstones, with some grits. It is found to the west of the Longmynd, near Pulverbatch, Ratlinghope and Wentnor.

3. *The Oakswood Group.*—This is made up of red-purple grits and conglomerates, which crop out east of Pontesford Hill, and along the higher ground from there to Linley Hill. In the northern part of the outcrop three conglomerates can be distinguished (Fig. 11, p. 25), of which the middle one, the Oakswood Conglomerate, contains 50 or 60 per cent of pebbles of volcanic rock. In the south part of the outcrop, near Linley Hill, at least two conglomerates occur (Fig. 10, p. 22).

Purple grits and conglomerates that seem to belong to the Western Longmyndian crop out near Caer Caradoc, and again near Hopesay.

The rocks of the pre-Cambrian inliers at Pedwardine, seven miles south, and of Old Radnor sixteen miles south-east, of Hopesay, are purple grits and conglomerates of Western Longmyndian type that probably belong to the Bayston Group. The inlier at Huntley, near May Hill, in Gloucestershire, shows grits and shales that are probably Longmyndian, though it is difficult to assign them to any of the groups recognized in Shropshire.

The resemblance of the volcanic fragments in the Western Longmyndian grits and conglomerates to the Uriconian rocks suggests that the latter are, at least in part, the older. Although some parts of the Eastern Longmyndian or Stretton 'Series' contain much volcanic material, there appears to be no strong evidence that this was derived from the Uriconian rocks, except that in the Helmeth Grits at the base of the Watling Shales. On the Longmynd the Western Longmyndian beds appear to rest upon the Eastern Longmyndian, and J. F. Blake thought that there was an unconformity between them. If this were so, the Uriconian rocks might conceivably be intermediate in age. Callaway and Lapworth, however, would not admit the existence of this unconformity. There is every indication that the westward dip of the Stretton 'Series' preserves the true order of succession. On the other hand, more than one line of evidence suggests that the Wentnor 'Series,' with the same direction of dip, is inverted. There is thus the possibility that the junction between the Stretton and the Wentnor 'Series' is a fault. This certainly seems to be the case on Haughmond Hill, where the Wentnor 'Series' is in contact with rocks that seem to belong to the Burway Group. The age relations of the two Longmyndian and the two Uriconian groups can, however, not yet be regarded as settled.

Basic intrusions in the Longmyndian rocks are mainly of the quartz-dolerite type, though olivine-dolerite, or basalt, occurs on Haughmond Hill and at Plealey. The quartz-dolerites rarely contain much free quartz, but they are characterized by the presence of a microscopic intergrowth of quartz and felspar (acid mesostasis) in the interstices between the large crystals. Their characters are

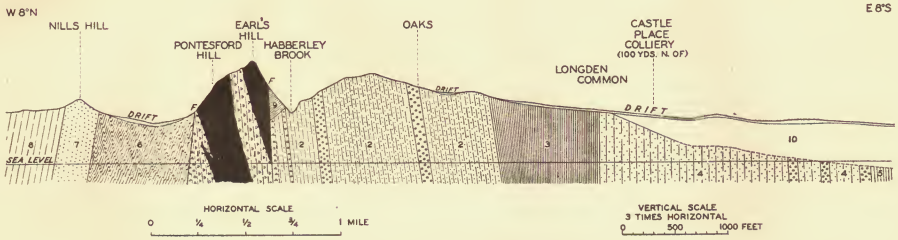


FIG. 11.—*Section across Nills Hill, Pontesford Hill and the Oaks.*

1. Uriconian; 2. Oakswood Group; 3. Bridges Group; 4. Bayston Group; 5. Stretton 'Series'; 6. Cambrian (Shineton) Shales; 7. Stiperstones Quartzite; 8. Mytton Beds; 9. Caradocian (Pontesford) Shales; 10. Coal Measures.

Intrusive dolerite: black. F-F, faults.

identical with those of dykes and sills in the Cambrian and Ordovician strata near Pontesbury, and they are probably post-Ordovician in age.

Mineral Veins in the Longmyndian Rocks.—Barytes (barium sulphate) is found, in places, as veins along faults and joints in the rocks of the Wentnor 'Series.' The faults, in the area south-east of Pontesbury, tend to run either from east-north-east to west-south-west or from east-south-east to west-north-west. In the former case they, and the veins with them, are inclined southward; in the latter northward. The barytes is found in discontinuous 'bunches' or swellings between which the vein is either very narrow or absent altogether. The barytes is usually stained pink by oxide of iron, and is of a platy habit, though occasional part-grown crystals showing the form characteristic of the mineral are found. The mineral is often discoloured by or encrusted with 'bitumen.'

Small quantities of copper ore are found in places, for the most part as stains or encrustations upon barytes or calcite. They are usually in the form of the green carbonate of copper (malachite), accompanied by the grey sulphate (chalcocite); but the blue carbonate (azurite) was formerly worked at the Westcott Mine, and the sulphate of copper and iron (bornite) occurs at Medlicott, near Wentnor.

III. CAMBRIAN

THE CAMBRIAN ROCKS are of great interest as being the most ancient sediments in this country to contain a recognizable sequence of fossils (Fig. 12, p. 28); although the variety of animal life which is represented in this oldest Cambrian fauna makes it certain that the ancestors of these forms must have existed in pre-Cambrian times.

The deposition of the Cambrian sediments was preceded by the folding and prolonged denudation of the pre-Cambrian rocks with the formation of an approximately level surface over which a great transgression of the sea took place, in which the basal Cambrian deposits were laid down with strong unconformity on the older rocks. The types of trilobites, brachiopods and pteropods which are the main constituents of the fauna in the oldest Cambrian rocks show a remarkable similarity to one another in widely separated areas, a fact which suggests that the extension of the sea at this period was world-wide, and that similarity of conditions allowed the dispersal of the same types over a great part of the marine areas of the world.

The Cambrian rocks of the Welsh Borderland are brought to the surface in two principal areas associated the one with the Eastern Uriconian axis of Shropshire extending from Lilleshall and the Wrekin (Fig. 13, p. 29) to the Caradoc and Comley (Figs. 14 and 15, pp. 30, 31) district, the other with the ancient Malvernian axis of Herefordshire and Worcestershire (Fig. 17, p. 35). Smaller areas of these rocks are also found between Pontesbury and Lydham and at Pedwardine in association with the Western Uriconian axis of Shropshire.

The Cambrian sediments found in these areas have been divided into three main series as follows:—

The Lower Cambrian, characterized by the *Callavia* [*Olenellus*] fauna of trilobites and consisting mainly of sandstones, with a quartzite at the base followed by glauconitic sandstones containing beds of shale and a thin development of fossiliferous sandy limestones at the top.

The Middle Cambrian, comprising shales, glauconitic grits and lenticular limestones with a fauna characterized by the trilobites *Paradoxides* and *Doryspyge*.

The Upper Cambrian, consisting mainly of shales with calcareous concretions and containing the trilobite *Parabolina spinulosa* and the small brachiopod *Orusia lenticularis*.

(Included with the Upper Cambrian are shales with the earliest known graptolite, *Dictyonema*, and the trilobites *Shumardia pusilla*, *Euloma monile*, *Asaphellus homfrayi*, etc. These are the Shineton Shales of Shropshire and the Bronsil or Grey Shales of the Malvern district.)

Lower Cambrian.—In Shropshire the basal Wrekin Quartzite, a shallow-water deposit in which the sand grains are well rounded and therefore probably derived from a wind-swept continental area, is

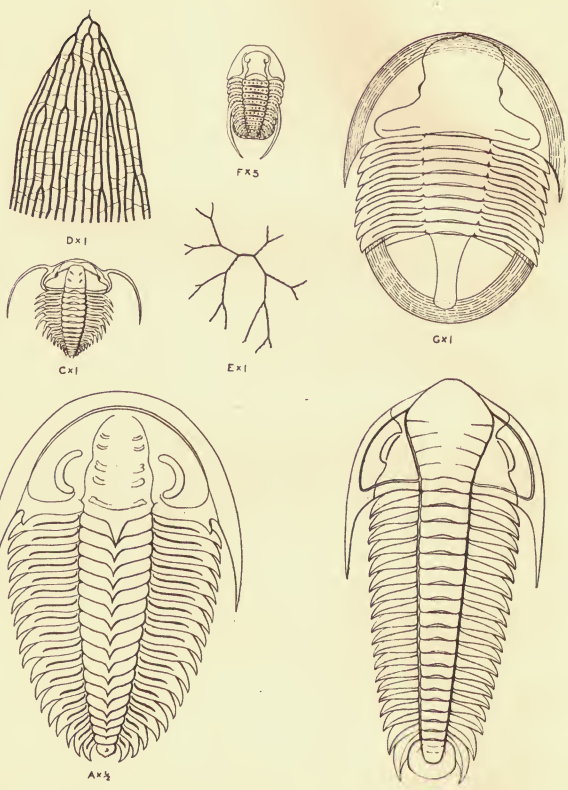


FIG 12.—*Cambrian Fossils.*

A. *Callavia callavei* (Lapworth), Lower Cambrian.
B. *Paradoxides hicksi* Salter, Middle Cambrian.
C. *Ctenopyge flagellifera* (Angelin), Dolgelly Beds, Upper Cambrian.
D. *Dictyonema flabelliforme* (Eichwald), Tremadoc Beds, Upper Cambrian.
E. *Clonograptus tenellus* (Linnarsson), Tremadoc Beds, Upper Cambrian.
F. *Shumardia pusilla* (Sars), Tremadoc Beds, Upper Cambrian.
G. *Asaphellus homfrayi* Salter, Tremadoc Beds, Upper Cambrian.

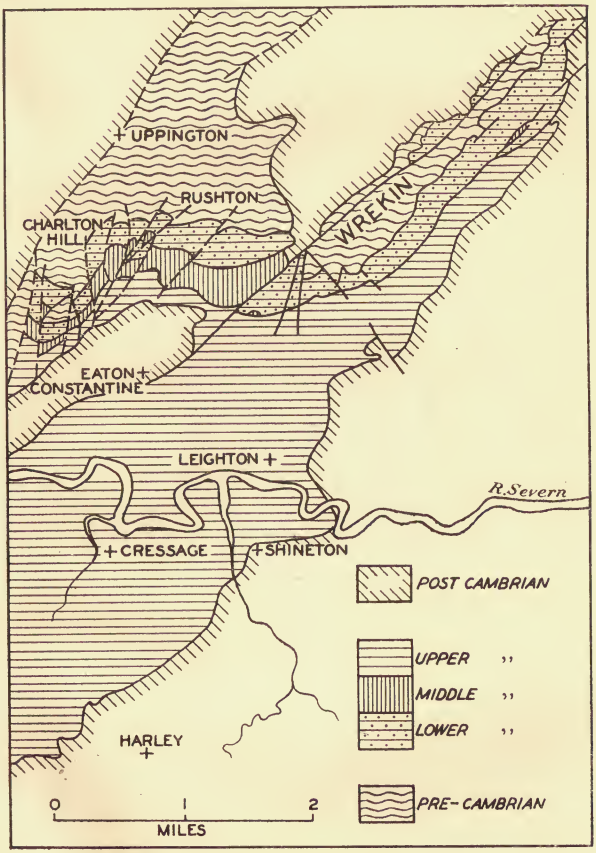


FIG. 13.—*Cambrian Rocks of the Wrekin District.*

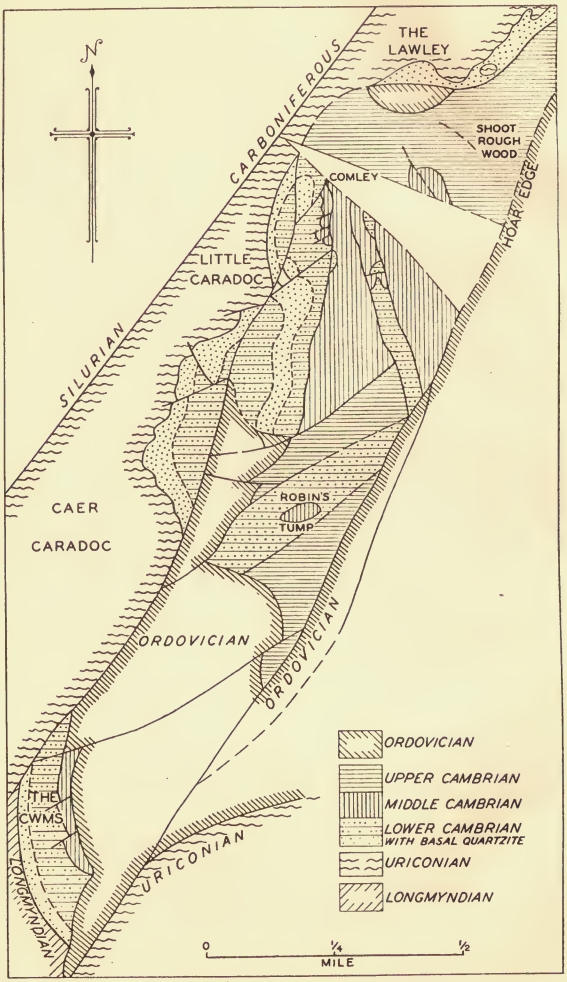


FIG. 14.—*The Cambrian Area of Comley, Shropshire.*
(After E. S. Cobbold.)

normally a pure white rock of fine grain. It is well exposed on both flanks of the Wrekin, to a thickness of about 150 ft., resting unconformably on the Uriconian rhyolites and tuffs of the range and containing, in its lower layers, many fragments of those older rocks. Towards the west good exposures can be seen in the Rushton Syncline where the quartzite rests upon the Rushton Schist, and again in the Charlton Hill Anticline where it overlies Uriconian volcanic rocks; but in these areas the thickness is less than at the Wrekin. It is also found on the east flanks of the Lawley and Caer Caradoc in contact with the Uriconian rocks of those hills.

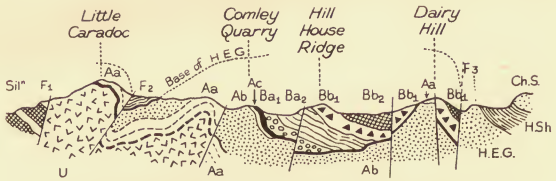


FIG. 15.—*Generalized section across the Comley Cambrian Area, showing the principal tectonic features.* (After E. S. Cobbold.)

[Length = about ½ mile.]

The Silurian on the west is part of the All Stretton Outlier, showing Wenlock and Aymestry Limestones.

Caradocian: Ch.S. = Chatwall Sandstone; H.Sh. = Harnage Shale; H.E.G. = Hoar Edge Grit. Cambrian: Bb2 = *Paradoxides intermedius* Shale; Bb1 = *P. intermedius* Grit and Breccia; Ba2 = *P. groomi* Shale; Ba1 = *P. groomi* Grit and Conglomerate; Ac = Comley Limestones (*Lapworthella, Protolenus, Strenuella, Callavia*); Ab = Lower Comley Sandstone; Aa = Wrekin Quartzite; U = Uriconian.

Thickened sinuous lines indicate three unconformities: (1) at the base of the Cambrian (over Little Caradoc); (2) at the base of the Middle Cambrian (Comley Quarry to Dairy Hill); (3) at the base of the Caradocian (from near F_2 to F_3).

The basal quartzite has not been detected in the Cambrian areas associated with the Western Uriconian rocks.

In the Malvern district a similar quartzite, the Malvern Quartzite, forms the base of the Cambrian and contains bands of conglomerate with pebbles of metamorphic quartzite, rhyolite, andesite and red granophyre, which suggest derivation principally from the rocks of the pre-Cambrian Malvern complex. It is poorly exposed, and its thickness cannot accurately be estimated, but T. T. Groom thought it might have been several hundred feet thick, though only 50 or 60 ft. of it can now be seen.

In the Wrekin-Caradoc district the Quartzite is succeeded by the Lower Comley Sandstone with narrow bands of conglomerate and greenish-grey sandstones at the base containing the oldest fauna known in the district; small horny-shelled brachiopods and species of *Hyolithus*. The main part of this division is a fine-grained greenish

micaceous sandstone. The green coloration is due to grains of the mineral glauconite, the presence of which indicates that the beds were formed in a moderately shallow sea. Some bands of shale are interbedded with the sandstone. Fossils are not common, but various species of horny brachiopods and fragments of trilobites have been found.

In the Malvern district a comparable sandstone, the Hollybush Sandstone, succeeds the Malvern Quartzite. It consists of green flaggy sandstone with thin calcareous layers. Fossils are fairly common and include small horny brachiopods such as *Micromitra phillipsi*.

A group of highly fossiliferous sandy limestones, totalling about 6 ft. in thickness, occurs at the top of the Lower Cambrian in the Wrekin-Caradoc district of Shropshire. From an exposure of these beds in Comley Quarry, Lapworth, in 1888, recorded a species of *Olenellus*, and later Groom obtained *Paradoxides* from the same quarry. From 1906 to 1936 Cobbold worked almost continuously at the fauna of these sandy limestones and divided them into zones characterized by the trilobites *Callavia* [*Olenellus*], *Eodiscus bellimarginatus*, *Strenuella* and *Protolenus*. The highest bed of limestone contains a small pteropod shell, *Lapworthella nigra*, and is regarded as the local top of the Lower Cambrian rocks.

At Comley this fossiliferous group begins with a bed of very green sandstone containing numerous fossils of the *Callavia* fauna. It merges upwards into the *Olenellus* (*Callavia*) Limestone of Lapworth, which consists of nodules of red or purplish sandy and micaceous limestone of a total thickness of about 2 ft. 6 in. This is followed by the *Eodiscus bellimarginatus* Limestone containing a somewhat similar fauna, less sandy material and, in its upper part, a considerable amount of phosphatic matter. Its thickness is about 1 ft. 9 in. The *Strenuella* Limestone, which is the next horizon, is again more sandy and somewhat red or purple except where fossils are plentiful, when it is grey. It contains some small pebbles of quartz and much phosphatic material; the thickness is about 9 in. The *Protolenus* Limestone has very little sandy material, is pale grey where fossiliferous but dark and phosphatic where fossils are scarce; thickness about 6 in. The *Lapworthella* Limestone at the top is largely made up of phosphatic matter with some sand and a few quartz pebbles. The thickness is rarely so much as 6 in., and it frequently thins out altogether. This variation in thickness may be due to erosion, as fragments of it have been found in the overlying Middle Cambrian conglomerate.

A strictly comparable sequence of zones has been worked out by Cobbold and Pocock in the Rushton area near the Wrekin, but in the Malvern area these zones have not, as yet, been recognized.

Middle Cambrian.—In the Shropshire area a break in the continuity of deposition occurred between the formation of the Lower Cambrian limestones and the overlying Middle Cambrian conglomerates, grits and shales (Fig. 16, p. 33). During this interval the lower beds appear to have been consolidated, folded and partly worn

away before the lowest Middle Cambrian beds were deposited. In the latter there are fragments of rock containing a Lower Cambrian fauna enclosed in a matrix of sediment with Middle Cambrian fossils.

The Middle Cambrian deposits consist of alternations of glauconitic sandstones and grits with shales and some conglomerates. These beds were laid down in a moderately shallow sea swept by gentle currents which distributed the debris produced by the wearing away of the older rocks. At intervals the current action must have been reduced to allow of the deposition of the fine-grained shaly beds.

The most characteristic fossils of the Middle Cambrian at Comley are various species of the trilobite genus *Paradoxides*, and the whole thickness of the beds can be divided, as has been done in Scandinavia, into a number of zones named after different species of this trilobite

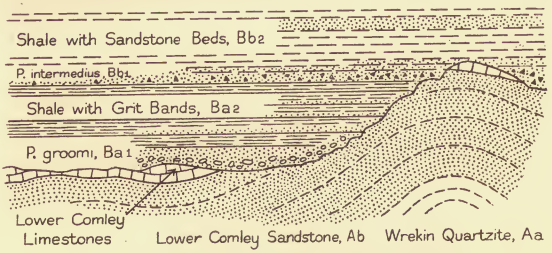


FIG. 16.—*Hypothetical section of disturbed and eroded Lower Cambrian beds during the deposition of the Middle Cambrian.* (After E. S. Cobbold.)

(The left-hand end of the section indicates conditions that might obtain during the accumulation of the *Paradoxides groomi* conglomerate, Ba1, of Comley Quarry Ridge; the right-hand end, those that might give rise to the formation of the Breccia-Bed, Bb1, of Comley Brook and Dairy Hill. The present horizontal distance apart is from 100 to 200 yds.; the thickness of the shales (Ba2) is estimated at 300 ft.)

genus. In Shropshire the lowest beds of this series contain *Paradoxides groomi* associated with another trilobite, *Dorypyge lakei*, and correspond to the *Paradoxides oelandicus* Zone of Scandinavia. These are followed by the *Paradoxides intermedius* Beds, comprising grits and breccia with a fauna equivalent to that of the *Paradoxides tessini* Zone of Scandinavia, the *P. rugulosus* Sandstone, and the *P. davidis* Grits containing many fossils characteristic of the *P. davidis* Horizon of Scandinavia.

The *Billingsella* Beds at the top of the Middle Cambrian contain many species of brachiopods which are found in the *P. forchhammeri* Zone of Scandinavia.

In the Rushton area also a sequence, comparable in part with that at Comley, has been worked out.

In the Malvern district the Middle Cambrian is probably represented in part by the upper portion of the Hollybush Sandstone, but no zonal

sequence has as yet been recognized. According to Groom, the shaly basal beds of the Hollybush Sandstone probably correspond with the '*Olenellus*' Beds, and with the Zone of *Paradoxides groomi* of the Comley area. The bulk of the Hollybush Sandstone possibly represents the greater part of the Paradoxidian of other localities.

Upper Cambrian.—In Shropshire the Upper Cambrian succession has been worked out in the Wrekin-Caradoc area. It commenced with the deposition of about 65 ft. of dark grey micaceous shales, with some calcareous concretions, which have yielded the brachiopod *Orusia lenticularis* and the trilobite *Parabolina spinulosa*, and was followed by about 15 ft. of black shales with numerous black, bituminous limestone concretions ('stinkstones') aligned along the bedding planes. These nodules are of the cone-in-cone type with a homogeneous limestone kernel containing the trilobites *Ctenopyge flagellifera* and *Eurycare angustatum* in abundance. The fauna represents a passage between the Subzone of *Leptoplastus-Eurycare* and that of *Ctenopyge flagellifera* as defined in Sweden. The total 80 ft. of shales are regarded as the partial equivalents of the thick Dolgelly Beds of North Wales.

At Malvern the Black (Whiteleaved Oak) Shales yield a somewhat similar fauna and are believed to be of approximately the same age.

The succeeding Shineton Shales of Shropshire, which have their equivalents in the Bronsil or Grey Shales of Malvern, are correlated with the Tremadoc Beds of North Wales. They are blue-grey shales with an estimated thickness of about 3,000 ft., in which the following succession in descending order has been worked out:—

6. Arenaceous Beds.
5. Zone of the trilobite *Shumardia pusilla*.
4. Brachiopod Beds.
3. Zone of the graptolite *Clonograptus tenellus*.
2. Transition Beds.
1. Zone of the graptolite *Dictyonema flabelliforme*.

The three lower divisions can be examined in Cherme's Dingle, south of the Wrekin, in a practically continuous section; while in Shineton Brook on the south side of the Severn Valley a fairly complete sequence is obtained from the Brachiopod Beds to the Zone of *Shumardia pusilla*, which contains many trilobites including *Asaphellus homfrayi*. The Arenaceous Beds can be seen farther to the south-west near Evenwood. Shales yielding *Dictyonema flabelliforme* are recorded from the Lawley District and also near Cardington, where *Clonograptus tenellus* occurs as well.

Farther to the west, in the area between the Longmynd and the Stiperstones, sandy shales yielding *Dictyonema*, *Clonograptus tenellus* and *Shumardia pusilla* extend as a narrow outcrop from Granham's Moor (Habberley) in the north to Snead (near Lydham) in the south.

A faulted inlier at Pedwardine near Brampton Bryan contains Shineton Shales of the Zone of *Dictyonema flabelliforme*.

The fine-grained character of the deposits of the Upper Cambrian and their remarkable uniformity indicate a deepening of the sea after the Middle Cambrian had been laid down and a gradual depression of the area keeping pace with the deposition of fine mud.

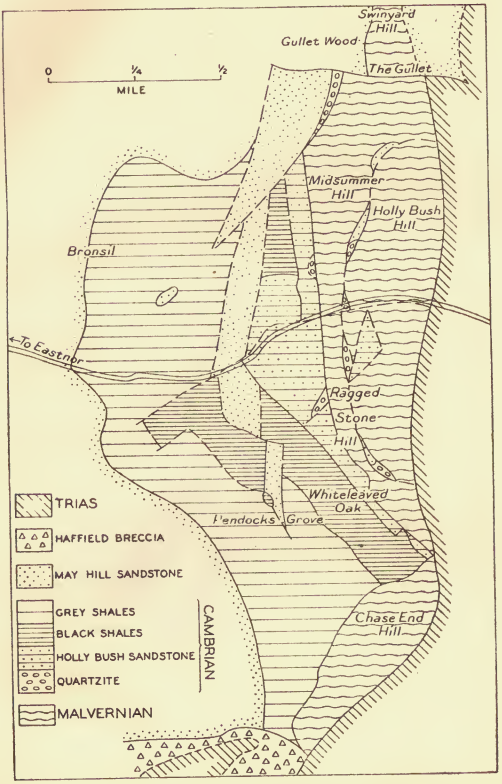


FIG. 17.—*The Cambrian Area of the Southern Malverns.*
(After T. T. Groom.)

The peculiar cone-in-cone concretions occur at various levels throughout the shales.

The Bronsil or Grey Shales of Malvern occupy a considerable area west of the Southern Malverns. They are usually of a light-blue, light-green or yellowish tint and are believed to have a total thickness of about 1,000 ft. The most abundant fossil is *Dictyonema flabelliforme;*

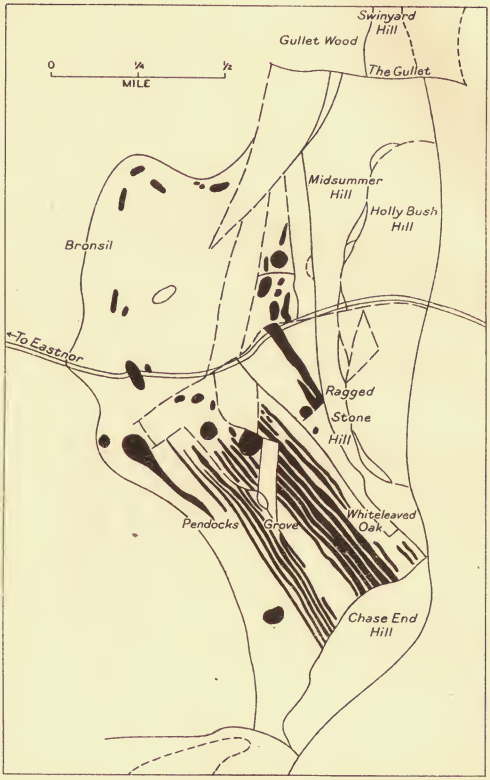


FIG. 18.—*Igneous Intrusions in the Cambrian of the Southern Malverns.*
(After T. T. Groom.)

the trilobites *Parabolinella triarthra*, *Symphysurus croftii* and others also occur.

Igneous Intrusions in the Cambrian Rocks.—There do not appear to be any contemporaneous igneous rocks in the Cambrian beds of the Welsh Borderland, but intrusions of later date, probably

late Ordovician, occur in the Shineton Shales at Maddocks Hill east of the Wrekin and near Eastridge in the Pontesbury district.

The Maddocks Hill rock occurs as a dyke or sill in the nearly vertical Shineton Shales and crops out over a distance of half a mile with a maximum width of 90 yds. The shales are baked and otherwise altered by the intrusion for some 25 yds. from the junction. The rock, which has been described as a camptonite, is of fine-grained crystalline type and consists mainly of felspar, augite, decomposed olivine and hornblende. Its mottled appearance is due to the contrast between the pink felspar crystals and the dark-green colour of the other minerals. A very similar type is intrusive in the Cambrian rocks of the Malvern district, at Nuneaton, in Leicestershire and in other Cambrian areas of England and Scotland.

In the Malvern area there are, besides the camptonite type, olivine-bearing dolerites and diabases which penetrate both the Grey and Black Shales and more rarely the Hollybush Sandstone (Fig. 18, p. 36).

The intrusions in the Pontesbury district occur as small dykes and sills of dolerite and quartz-dolerite.

IV. ORDOVICIAN

ORDOVICIAN ROCKS APPEAR at the surface only in the northern part of the Welsh Border district—in Shropshire, the adjacent parts of Montgomeryshire, and at Pedwardine in Herefordshire. In the southern part of the district Ordovician rocks are probably absent, for near the Malvern Hills and elsewhere Silurian strata rest directly upon Cambrian and pre-Cambrian rocks.

The Ordovician rocks are found in four principal areas, namely: the Breidden Hills; the Stiperstones, Shelve and Chirbury area; the Pontesford area; and the 'Caradoc' area (around Acton Burnell, Cardington and Cheney Longville).

The pre-Cambrian and Cambrian rocks seem to have formed, in early Ordovician times, a land mass, against the western margin of which the Ordovician strata were deposited. The gradual sinking of this land allowed newer members of the system to be deposited successively farther eastward; but only the higher (Caradoc) beds are represented in the Pontesford and 'Caradoc' areas. Still farther east, in Central England, Ordovician rocks are absent altogether (Fig. 19, p. 39).

Further, considerable denudation of the Ordovician rocks took place in early Silurian times, so that, even in the northern part of the present district, the Silurian strata rest, in different places, on various parts of the Ordovician System, and even upon pre-Ordovician rocks. The highest Ordovician beds (the Ashgill Series), if present, are everywhere concealed, though they appear in the neighbouring district of North Wales.

Many of the Ordovician rocks are fossiliferous (Fig. 20, p. 40). In the western areas of outcrop they consist largely of shales and flags, and in such beds graptolites are not uncommon. It is therefore possible to divide the strata into zones, each characterized by the association of certain species of graptolites and each named after a prominent species. The recognition of these zones enables the strata of one area to be readily compared and correlated with those of others and with the Ordovician rocks of neighbouring districts.

THE STIPERSTONES, SHELVE AND CHIRBURY AREA (Pl. XI)*

In this area (Fig. 21, p. 41) the sequence of the Ordovician rocks seems to be nearly complete, except for the absence of the Ashgill Series. Apart from the basement beds (the Stiperstones Quartzite), which indicate the proximity of a shoreline to the east, the strata were probably deposited in quiet and moderately deep water, with

* *See* map at end of volume.

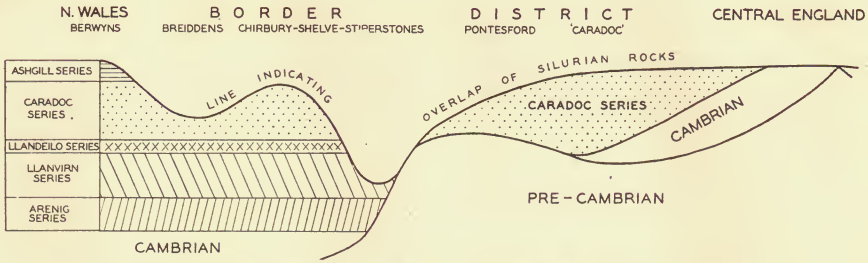


FIG. 19.—*Diagram to illustrate the relation of the Welsh Border District to North Wales, where the sequence of Ordovician Rocks is complete, and to Central England, where these rocks are absent.*

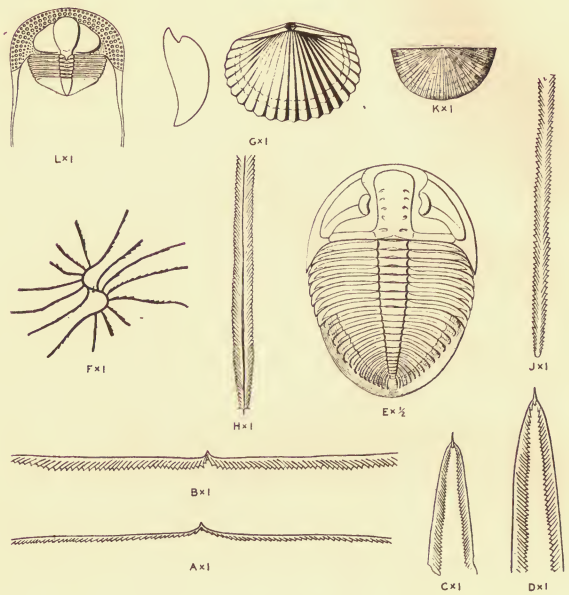


FIG. 20.—*Ordovician Fossils.*

(All graptolite drawings after Elles and Wood.)

A. *Didymograptus extensus* (Hall), Mytton Flags, Arenig Series.
B. *Didymograptus hirundo* Salter, Mytton Flags, Arenig Series.
C. *Didymograptus bifidus* (Hall), Llanvirn Series.
D. *Didymograptus murchisoni* (Beck), Betton Beds, Llanvirn Series.
E. *Ogygiocaris* [*Ogygia*] *buchi* (Brongniart), Meadowtown Beds,* Llandeilo Series.
F. *Nemagraptus gracilis* (Hall), Rorrington Beds, Caradoc Series.
G. *Orthis* (*Dinorthis*) *flabellulum* J. de C. Sowerby (two views), Hoar Edge Grit, Caradoc Series.
H. *Diplograptus* [*Mesograptus*] *multidens* Elles and Wood, Pontesford Shale, Caradoc Series.
J. *Orthograptus truncatus* Lapworth, Harnage Shale, Caradoc Series.
K. *Sowerbyella sericea* (J. de C. Sowerby), Chatwall Group, Caradoc Series.
L. *Cryptolithus* [*Trinucleus*] *concentricus* Eaton, Caradoc Series.

* This species-group ranges in Shropshire from the Hope Shales (Llanvirn) to the Rorrington Shales (Caradoc) [C. J. Stubblefield].

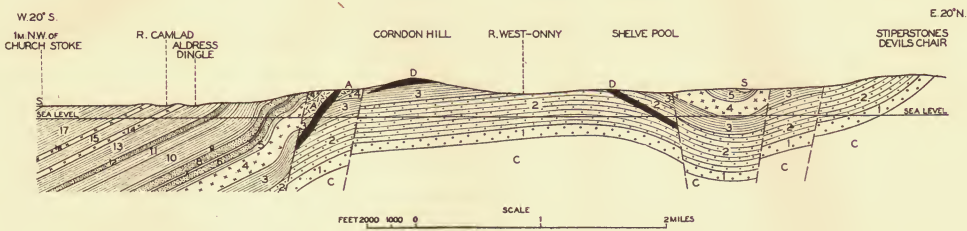


FIG. 21.—*Section across the Stiperstones, Shelve and Chirbury Area.*

(Based upon map by C. Lapworth.)

1. Stiperstones Quartzite; 2. Mytton Beds; 3. Hope Shales; 4. Stapeley Volcanic Group; 5. Stapeley Shales; 6. Lower Weston Grit; 7. Weston Shales; 8. Upper Weston Grit; 9. Betton Shales; 10. Meadowtown Beds; 11. Rorrington Flags and Shales; 12. Spy Wood Grit; 13. Aldress Shales; 14. Hagley Volcanic Group; 15. Hagley Shales; 16. Whittery Volcanic Group; 17. Whittery Shales; C. Cambrian; S. Silurian; D. Dolerite; A. Andesite.

occasional influxes of coarser sediment and outbursts of activity from volcanic islands or submarine craters. The strata were divided by Charles Lapworth into a number of groups (herein referred to as Stages), whilst the igneous rocks of the area have been made known largely by the studies of W. W. Watts.

Arenig Series.—The Arenig Series consists of the Mytton Stage, which begins with the Stiperstones Quartzite, a hard white or cream-coloured siliceous sandstone, in parts conglomeratic. This gives rise to the crags of the Stiperstones, such as the Devil's Chair and Cranberry Rock, and is also well exposed in quarries near Pontesbury. Worm-casts constitute the chief traces of organisms in this formation.

The Mytton Beds, which follow, consist of hard flags and shales, of which the spoil-heaps of the lead mines near Shelve are composed. In some of the beds horny-shelled brachiopods, *e.g. Monobolina* [*Obolella*] *plumbea* (Salter), and rather large trilobites, *e.g. Niobella* [*Ogygia*] *selwyni* (Salter), are found. In the higher beds, extensiform graptolites (in which the branches, or 'stipes,' are in line) occur, and the zones of *Didymograptus extensus* and of *D. hirundo* can be recognized. The shales exposed near Shelve church have yielded graptolites in comparative abundance.

Llanvirn Series.—This Series begins with the Hope Stage, consisting of shales in which graptolites of 'tuning-fork' shape are found. In the middle and upper part of the Hope Shales there occur bands of very fine-grained volcanic tuff, or 'china-stone ash,' well seen near Hope rectory.

The Hope Shales are followed by the Stapeley Volcanic Group, in which tuffs, breccias and some lavas are interbedded with shales. Stapeley Hill is formed of this group, and a well-known section in it is that of Tasgar Quarry, by the side of the main road from Minsterley to Bishops Castle, about one and a quarter miles north-north-west of Hyssington. The tuffs and lavas of this group indicate a period of volcanic activity corresponding with that which gave rise to the volcanic rocks of the Arenigs and Cader Idris in North Wales. The Stapeley Volcanic Group, and the succeeding Stapeley Shales, constitute the Stapeley Stage, in which brachiopods, trilobites and other fossils are found. The graptolites are of the same 'tuning-fork' type as those in the Hope Shales, and the Hope and Stapeley Stages, together, belong to the Zone of *Didymograptus bifidus*.

The Llanvirn Series is continued by the Weston Stage, which is composed of two belts of grits, separated by flags and shales. The flags yield numerous trilobites and bivalve molluscs, with brachiopods, but no graptolites. The grits contain material of volcanic origin. Exposures of them can be seen at Priestweston, about two miles south-west of Chirbury.

The Betton Stage, which follows, again consists of shales and flags, which contain 'tuning-fork' graptolites of a kind characteristic of the higher part of the Llanvirn Series (Zone of *Didymograptus murchisoni*). There are, also, brachiopods and trilobites, amongst the latter being

Ogyginus [*Ogygia*] *corndensis* (Murchison), a species that occurs also in the Weston Stage below, and in the Meadowtown Stage above.

Llandeilo Series.—The Llandeilo Series is represented by the Meadowtown Stage, which consists of shales with discontinuous beds of limestone and calcareous flags. One or two tuffaceous bands would seem to constitute the only traces, in this area, of the great volcanic series of Snowdonia. The fossils include many trilobites, brachiopods and molluscs. Amongst the trilobites is the well-known species *Ogygiocaris* [*Ogygia*] *buchi* (Brongniart). *Basilicus* [*Asaphus*] *tyrannus* (Murchison) has been recorded, but it is doubtful whether the species actually occurs in this district. The graptolites are of an unbranched biserial type, having two rows of tooth-like projections (hydrothecae). The Meadowtown Beds appear to belong to the zone of *Glyptograptus teretiusculus*, but this index fossil has not yet been found in them.

Caradoc Series.—The lowest beds of the Caradoc Series are classed as the Rorrington Stage, comprising shales and flags of which the lower part is characterized by slender, branched, uniserial graptolites, whilst those in the upper part are mainly unbranched and biserial. These graptolites indicate the Zone of *Nemagraptus gracilis** and that of *Climacograptus peltifer* and *Diplograptus* [*Mesograptus*] *multidens*.

The Rorrington Flags are followed by the Aldress Stage, at the base of which is the Spy Wood Grit, a calcareous sandstone in which, amongst other fossils, the remains of a little waterflea-like animal, *Tetradella* [*Beyrichia*] *complicata* (Salter) are abundant. The grit passes up into the Aldress Shales, which include a band in which a many-branched graptolite of the genus *Dictyonema* is common. From other graptolites it appears that the Aldress stage belongs to the Zone of *Dicranograptus clingani*.

The Hagley Stage, which follows, consists of two volcanic groups, represented by tuffs, breccias and occasional lavas, separated by shales. The tuffs yield fossils, including sponge-spicules and graptolites. The fossils indicate that the stage represents the top part of the Zone of *Dicranograptus clingani* or the base of that of *Pleurograptus linearis*. A good exposure in the lower or Hagley Volcanic Group is afforded by a roadside quarry at Hagley, on the road from Priestweston to Chirbury; whilst the higher or Whittery Volcanic Group is exposed in quarries, near the same road, in the woods about a mile south-west of Chirbury. The shales separating the two volcanic groups are known as the Hagley Shales.

The highest or Marrington Stage consists of the Whittery Shales, soft shales similar to the Hagley Shales. These also, in places, yield fossils which indicate that they belong to the Zone of *Pleurograptus linearis*.

* In placing the *Nemagraptus gracilis* beds in the Caradoc Series the practice adopted by the Geological Survey in South Wales is here followed. Many authors begin the Caradoc Series with the Zone of *Climacograptus wilsoni*, which has not, up to the present, been recognized in the Welsh Border District.

The Ordovician rocks of this area are bent into folds and broken by faults. The chief folds are: a trough, or syncline, the axis of which runs by Venusbank, Ritton Castle and Pultheley; and an arch, or anticline, the axis of which runs near Hope, Shelve and Hyssington. In the deeper part of the Ritton Castle syncline beds up to the Stapeley Shales are brought in. The Shelve anticline brings up an inlier of the Mytton beds near Shelve (Fig. 21, p. 41).

Igneous intrusions.—Numerous igneous intrusions occur in the Stiperstones, Shelve and Chirbury area. These all consist of rocks of low or intermediate silica percentage. Some of them are quartz-dolerites exactly like those found in the Longmyndian and Cambrian rocks. These occur as dykes and sills, and they may be late Ordovician in age. In another type the orthorhombic pyroxene, hypersthene, is present, as well as the monoclinic pyroxene, augite. To this type belongs the rock that is intruded into the arch of the Shelve anticline, on Corndon Hill and to the south. Near Snead an intrusion of this type affects the basal Silurian rocks, as well as the Ordovician.

The rocks of intermediate silica-percentage are augite-andesites. These form the hills of Todleth, the Roundtain and Llanfawr, near Church Stoke, and appear also farther north. They cut across the bedded rocks of Llanvirn age; but their composition is so similar to that of the lavas in the Stapeley Volcanic Group that it is unlikely that they are very different in age.

Lastly, picrites, rocks very poor in silica (ultrabasic), are found in certain places, for example north of Hyssington and near Shelve Pool, in which latter locality, however, they are known only as boulders. These are the only intrusive rocks in this area that contain olivine.

Mineral veins.—Lead ore, as galena, and zinc ore, as blende, occur in veins in the Ordovician rocks of the Shelve area, in a matrix, or 'gangue,' of crushed country rock with quartz, calcite, barytes and, occasionally, pyrites and fluorspar. Secondary encrustations of malachite and 'pitch' are found in places. Lead was worked by the Romans and in mediaeval times, and both lead and zinc in modern times; but mining is now practically restricted to the associated barytes. The metalliferous veins occupy fault-fissures and are almost confined to the Mytton Beds, dying out where they meet the overlying Hope Shales. The Shelve anticline, by bringing up the Mytton Beds near Shelve, has rendered the veins accessible to the west of the main outcrop near the Stiperstones. The veins tend to course from north-west to south-east or from east-north-east to west-south-west. They do not show any direct connexion with the igneous intrusions, but may be related to a concealed mass of granite.

Veins of barytes, in some cases carrying a little galena, occur in some of the higher beds, such as the Stapeley, Hagley and Whittery Volcanic groups, and the Weston Grit. Again the faults or fissures become barren when they pass from these hard rocks into the interbedded shales.

A. THE CARADOC HILLS FROM THE LONGMYND

B.—THE BREIDDEN AND MOEL-Y-GOLFA

CORNDON HILL AND THE SHELVE AREA FROM NEAR MONTGOMERY

THE BREIDDEN HILLS

Near the Breidden Hills (Figs. 22, below, and 23, p. 46) the lowest Ordovician rocks are presumably concealed by the alluvium of the River Severn, or, perhaps, cut off by a fault under that alluvium. The higher beds are hidden by the unconformable Silurian rocks along the south-east flank of the hills.

The strata that crop out between belong to the lower part of the Caradoc Series; and nearly all appear to fall within one zone, that of *Climacograptus peltifer* and *Diplograptus* [*Mesograptus*] *multidens*. The lowest beds, however, seem to belong to the Zone of *Nemagraptus gracilis*. These Lower Shales are bent into an anticline, upon which

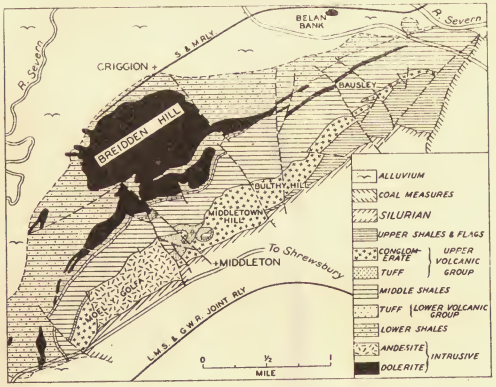


FIG. 22.—*Map of the Ordovician Rocks of the Breidden Hills.*
(After W. W. Watts, C. B. Wedd and others.)

minor folds are superimposed, and are intruded by dolerite that, as shown by W. W. Watts, follows the anticline in laccolitic form (Fig. 23, p. 46).

The Lower Shales are followed by a band of tuffs, in part of the fine 'china-stone' type, forming the Lower Volcanic Group. These tuffs are associated with a black grit that contains sponge-spicules. The Lower Volcanic Group is developed mainly in the western and middle part of the range, but is represented by hard splintery tuff in the bank of the Severn, north-east of Bausley.

The Lower Group is followed upwards, by the Middle Shales, and these, again, by the Upper Volcanic Group. This consists of white siliceous tuffs and 'china-stone,' followed upwards by the 'bomb-rock,' a coarse conglomerate containing many rounded boulders of andesite in a tuffaceous matrix. At the north-east end of

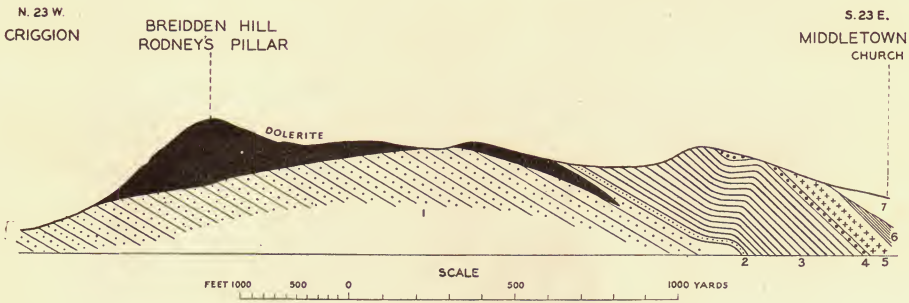


FIG. 23.—*Section across the Ordovician Rocks of the Breidden Hills.*
(Mainly after W. W. Watts.)

1. Lower Shales; 2. Lower Volcanic Group, tuff; 3. Middle Shales; 4. Upper Volcanic Group, tuff; 5. Upper Volcanic Group, conglomerate; 6. Upper Shales; 7. Silurian.

its outcrop this conglomerate is followed by bedded tuffs that contain fossils, including graptolites. The Upper Volcanic Group is succeeded by the Upper Shales, which include flags, and, in places, thin limestones.

The intrusive dolerite mentioned above is a hypersthene-dolerite similar to that of Corndon Hill. In addition, the Ordovician rocks are penetrated by a sill of andesite that forms the crest and south-east flank of Moel-y-Golfa. This sill is overlain unconformably by Llandovery (Lower Silurian) rocks.

THE PONTESFORD AREA

Near Pontesford Ordovician shales crop out along the Habberley or Pontesford Brook. They yield trilobites and graptolites, and belong to the Zone of *Climacograptus peltifer* and *Diplograptus* [*Mesograptus*] *multidens*. They thus correspond with part of the Rorrington Flags of the Shelve-Chirbury area, and with the greater part of the Ordovician rocks of the Breidden Hills.

At their base the shales become sandy and pass down into a conglomerate that rests unconformably upon the pre-Cambrian rocks. At one place, however, about one and a quarter miles south of Pontesford, the conglomerate rests upon the eroded surface of a rhyolite. This rhyolite is itself unconformable to the pre-Cambrian rocks, and may be of Ordovician age. Its strongly marked flow-banding seems to have an average direction parallel to the strike of the Caradocian shales; but the banding is much contorted, and in places the basal conglomerate truncates it abruptly.

THE ACTON BURNELL, CARDINGTON AND CHENEY LONGVILLE AREA

This, the ' Caradoc ' area of Ordovician rocks (Figs. 24 and 25, pp. 48, 49), extends in a strip about seventeen miles long from near Cressage to near Craven Arms; but it is divided into two by the Cardington Hills, which consist of igneous rocks generally supposed to be pre-Cambrian in age.

In this ' Caradoc ' area the Caradoc Series only, of the Ordovician System, is present—so far as known. The area was perhaps dry land when the Arenig, Llanvirn and Llandeilo rocks of the Shelve-Chirbury area were being deposited, and the Caradoc Beds themselves seem to have been formed in shallower water and nearer to land than those of the western areas, except, perhaps, that of Pontesford (Fig. 26, p. 50).

The series, generally speaking, is very fossiliferous and begins with the Hoar Edge Group, named after the prominent escarpment of Hoar Edge near Cardington. This group consists of conglomerates, grits and sandstones with shelly, calcareous beds. The grits contain wind-faceted pebbles and well-rounded sand grains and the group was probably deposited near an arid land, whence it derived its wind-eroded material. Uriconian rocks formed part of this land, for

fragments of them are common in the grits and conglomerates. In shale-bands interbedded with the sandstones the graptolite *Nemagraptus gracilis* has been found.

After the deposition of the Hoar Edge Group the area may have become dry land again, for there seem to be no beds corresponding

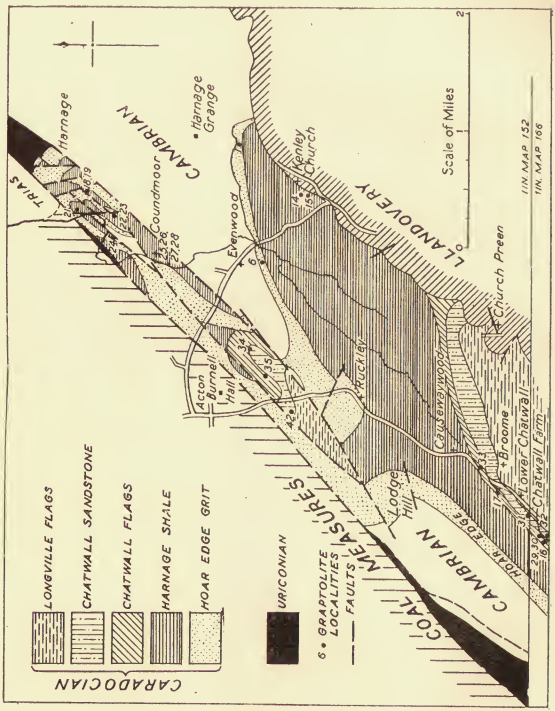


FIG. 24.—*Map of the Caradocian Rocks of the Chatwall, Acton Burnell and Harnage Areas.*

with the shales of Pontesford and the Breiddens and the Upper Rorrington Flags of the Shelve-Chirbury area.

The next group, the Harnage Group, consists of shales in which the graptolites indicate the Zone of *Dicranograptus clingani*. They thus are equivalent to the Aldress Shales of the Shelve-Chirbury area.

The Chatwall Group, which follows, yields similar graptolites. It is mainly sandy. The lower part consists of the '*Glyptocrinus* Flags,' so called from the abundance in them of stem segments of the 'sea lily' *Rhaphanocrinus* [*Glyptocrinus*] *basalis* (M'Coy). The middle part

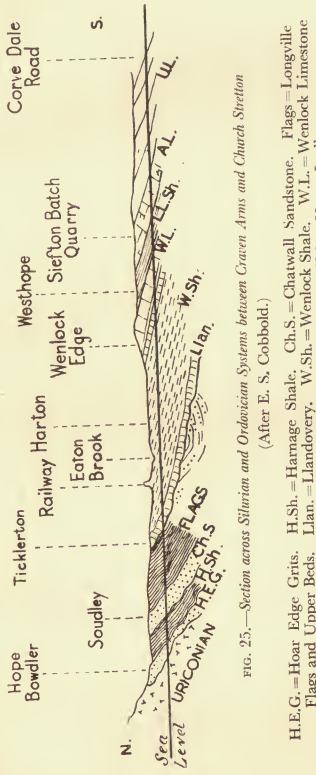


FIG. 25.—*Section across Silurian and Ordovician Systems between Craven Arms and Church Stretton*
(After E. S. Cobbold.)

H.E.G. = Hoar Edge Grits. H.Sh. = Harnage Shale. Ch.S. = Chatwall Sandstone. Flags = Longville Flags and Upper Beds. Llan. = Llandovery. W.Sh. = Wenlock Shale. W.L. = Wenlock Limestone L.L.Sh. = Lower Ludlow Shale. A.L. = Aymestry Limestone. U.L. = Upper Ludlow.

is called the Chatwall or Soudley Sandstone, and may perhaps be regarded as the typical 'Caradoc Sandstone' of Murchison. The sandstone is pebbly in places and, near Soudley, a purple banding is characteristic. At the top of the Chatwall Group a calcareous sandstone with numerous lenses of shelly limestone is developed. This

has been called the '*Alternata* Limestone,' from the abundance in it of the brachiopod *Orthis* (*Heterorthis*) *alternata* J. de C. Sowerby.

The Longville Group follows, and is the highest that crops out

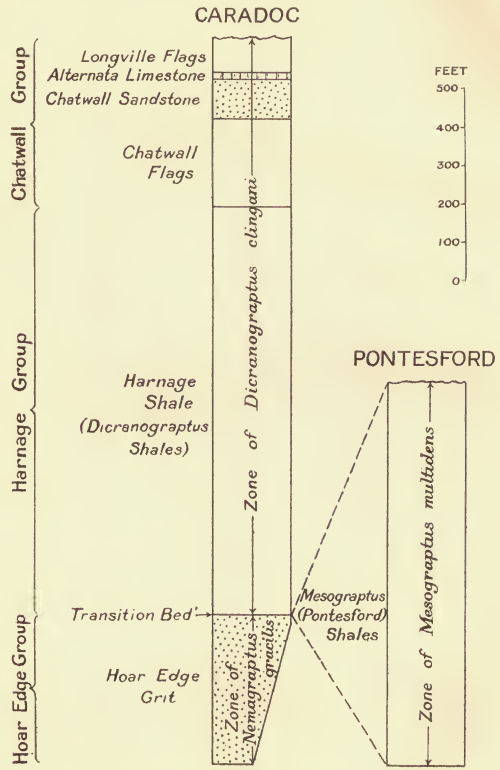


FIG. 26.—*The Caradocian Succession in the Caradoc and Pontesford Areas.*

north of the Cardington Hills. It consists of flags and shales, the highest shales being characterized by the trilobite *Trinucleus*. It is well exposed in the valley of the Onny River where, near Cheney

Longville, Silurian rocks rest unconformably upon the *Trinucleus* Shales.

The Acton Scott Group, known only south of the Cardington Hills, comprises shales in the lower part of which calcareous nodules are developed. These constitute the ' Acton Scott Limestone,' in which corals and other fossils are common. The upper part of the Acton Scott Group is called the Upper *Trinucleus* Shales.

No igneous intrusions are known in the Ordovician rocks of the ' Caradoc ' area.

V. SILURIAN

THE SEQUENCE OF the rocks of the Silurian System was first established by Sir R. I. Murchison in the Welsh Borderland, a district that includes most of the localities after which the subdivisions were named. The area has therefore come to be regarded as the classical and typical district for the study of these rocks, the highly fossiliferous character (Figs. 27 and 32, pp. 53, 61) and lithological variety of which render them of special interest to the palaeontologist and stratigrapher.

The Silurian deposits rest with strong unconformity on all divisions of the Ordovician, Cambrian, Longmyndian and Uriconian rocks; and individual beds show marked changes in lithology and fauna, when traced from one part of the district to another, due to the varying conditions under which they were deposited, such as depth of sea, distance from the shoreline and amount of terrigenous material swept into the area. Thus a calcareous shelly facies and an argillaceous graptolitic facies have been recognized, the former deposited in shallow water near land, the latter in deeper water at a distance from the shoreline. It is probable that the deeper water lay away to the north-west of the Longmynd-Old Radnor barrier of older rocks, which stood along the south-eastern margin of a geosyncline extending through Wales and the Lake District, while to the south-east of that barrier the shallower waters were diversified by islands, shoals and coral reefs.

The scenery of the Silurian ground is characterized by wooded scarps and valleys, such as Wenlock Edge and Hope Dale, caused by the differential weathering of the hard limestone and soft shale beds of the sequence.

The Silurian rocks fall into four main divisions:—

4. Downton Series.
3. Ludlow Series.
2. Wenlock Series.
1. Llandovery Series.

Llandovery Series.—In Lower Llandovery times, with the sea lying to the north-west of the Longmynd-Old Radnor axis of older rocks, no deposits of that period appear to have been laid down in the district to the south-east which we may assume to have been a land area. With the advent of Upper Llandovery times, however, the sea, owing to subsidence, gained access to that area and sandy or conglomeratic deposits were laid down along the irregular coastline of the partly submerged land mass whose outstanding features were those now known as the Breidden, Shelve, Longmynd, Caradoc and Malvern Hills.

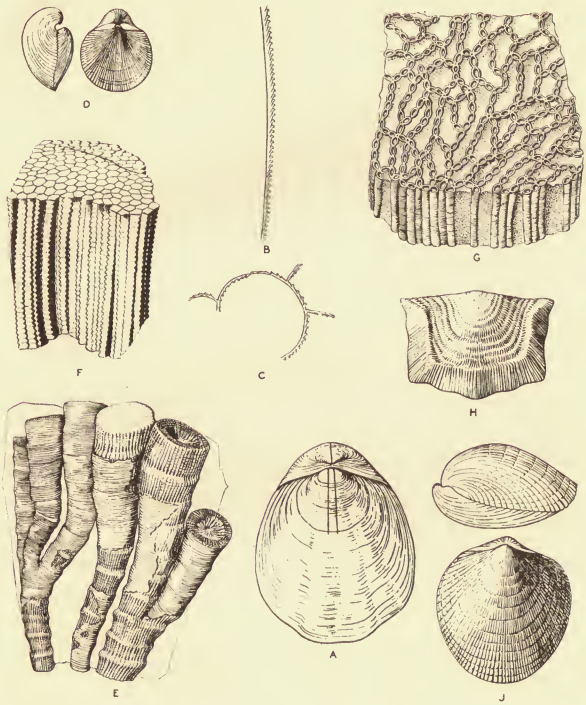


FIG. 27.—*Llandovery and Wenlock Fossils.*
(All natural size.)

A. *Pentamerus oblongus* J. de C. Sowerby, Upper Llandovery Beds.
B. *Monograptus riccartonensis* Lapworth, Wenlock Shale.
C. *Cyrtograptus lundgreni* Tullberg, Wenlock Shale.
D. *Orthis* (*Parmorthis*) *elegantula* Dalman, Wenlock Shale.
E. *Xylodes articulatus* (Wahlenberg), Wenlock Limestone.
F. *Favosites gotlandicus* Lamarck, Wenlock Limestone.
G. *Halysites catenulata* (Martini), the 'Chain Coral,' Wenlock Limestone.
H. *Leptaena rhomboidalis* (Wilckens), Wenlock Limestone.
J. *Atrypa reticularis* (Linnaeus), (two views), Wenlock Limestone.

The Upper Llandovery beds thus rest with strong unconformity on the rocks, ranging in age from Ordovician to pre-Cambrian, which constituted this old land mass. At the present day denudation has reached a stage at which the deposits of the ancient shoreline have been uncovered at many points and, as first observed by Ramsay about 1846 and recently demonstrated by Whittard, reveal in a striking manner such features as the actual pebble beaches and sea stacks of the Upper Llandovery sea; thus the Llandovery rocks at the southern end of the Longmynd are shown to have been deposited against a rugged coastline of Longmyndian rocks, and again at the Malverns a basal conglomerate, undoubtedly a shoreline deposit, contains angular fragments of the ancient pre-Cambrian rocks mixed with corals and shells of the Upper Llandovery fauna.

With continued subsidence of the land, fossiliferous, muddy and calcareous deposits, the *Pentamerus* Beds, were laid down, the most characteristic fossil being the brachiopod *Pentamerus oblongus*. In Harper's Dingle south-east of the Wrekin a thin conglomerate is developed, near the base of these beds, composed of Uriconian pebbles mixed with quantities of the shells of *P. oblongus*, indicating the proximity of a shoreline of Uriconian rock.

The *Pentamerus* Beds are succeeded by shaly sediments, the Purple or Hughley Shales. In Shropshire these purple and green mudstones and shales outcrop from near the Wrekin to the Onny River and around the Longmynd, Shelve and Breidden masses. They are apparently the equivalent of the Tarannon Shales of Central Wales.

In the Woolhope district (Figs. 28 and 29, pp. 55, 56) the Llandovery beds are represented by flaggy sandstones and shales with, at the top, purple shales and thin limestones containing the large brachiopod *Stricklandia lirata* and form a passage to the overlying Woolhope Limestone. In these passage beds there occurs a thin band of limestone crowded with the remains of the peculiar crinoid *Petalocrinus*.

At May Hill the sandstones are present in greater thickness and are conglomeratic in their lower part. The passage beds with *Stricklandia* and *Petalocrinus* are also to be found.

In the Malvern country (Fig. 29, p. 56) the Upper Llandovery deposits, with a basal fossiliferous conglomerate, rest on the Cambrian and pre-Cambrian rocks and pass up through purple shales and thin limestones, among which the *Petalocrinus* Limestone has been detected, into the overlying Woolhope Limestone. The passage beds here have been variously referred to as the Woolhope Shales, *Stricklandinia* Beds or Tarannon Shales.

At Presteign the uppermost beds are absent and the Woolhope Limestone rests on coarse grits with *Pentamerus oblongus*.

Wenlock Series.—The shelly facies of the Wenlock Series is well developed in the Wenlock Edge district, in the neighbourhood of Ludlow, at Malvern, in the inliers of Woolhope and May Hill and, less conspicuously, at Usk.

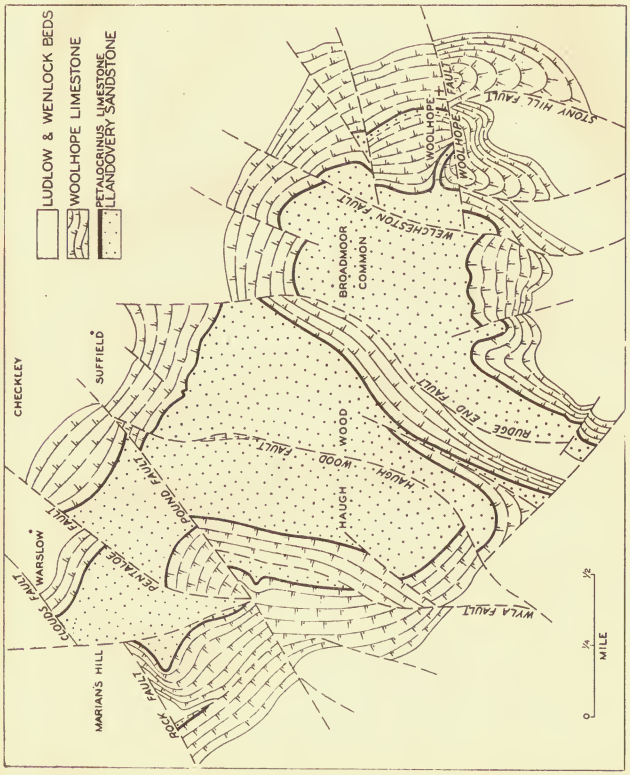


FIG. 28.—*Map of the Central Area of the Woolhope Anticline.*
(R. W. Pocock.)

The classification of the beds is based on the developments at Wenlock Edge and Woolhope, and three main divisions are recognized as follows:—

Wenlock Limestone.
Wenlock Shale.
Woolhope Limestone.

The fauna of these beds is abundant—especially in the Wenlock Limestone, which is rich in brachiopods, corals and crinoids. Grapto-

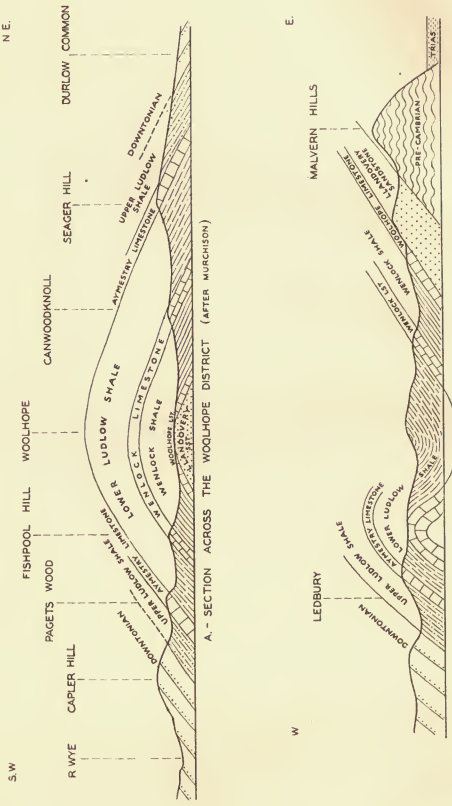


FIG. 29.—*Sections across the Silurian districts of Woolhope and Malvern.*

lites are scarce, but sufficient to allow correlation with the graptolitic facies.

The graptolitic facies which is present to the west and north-west of the old pre-Cambrian barrier is represented by blue or dark-grey shales which have yielded a series of graptolites and occasional shelly

fossils. In the Long Mountain syncline six zones have been recognized in descending order as follows:—

Zone of *Cyrtograptus lundgreni*
,, ,, *rigidus*
,, ,, *linnarssoni*
,, ,, *symmetricus*
,, *Monograptus riccartonensis*
,, *Cyrtograptus murchisoni*

Calcareous sediments such as are found in Wenlock Edge and in the south-eastern inliers are nowhere to be seen to the west and

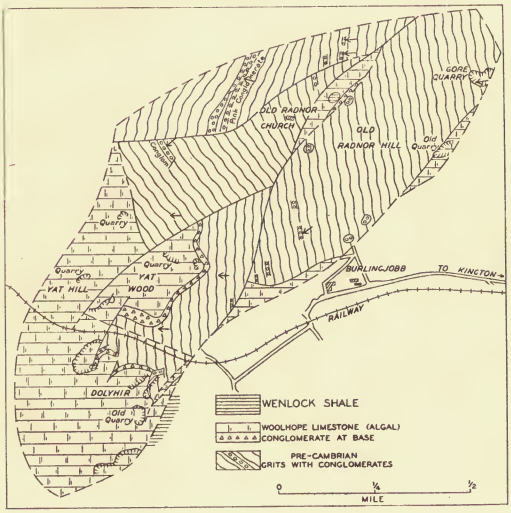


FIG. 30.—*Map of the Old Radnor Inlier.*
(After E. J. Garwood.)

north-west of the pre-Cambrian ridge, in which direction the deeper waters of the geosyncline were unfavourable to the life of the fauna characteristic of the shallower waters of the district to the south-east.

Woolhope Limestone.—The normal development of the Woolhope Limestone is exposed only in the south-eastern areas of Woolhope (Pl. VIII B), May Hill and the Malverns, where it consists of beds of blue flaggy limestone, frequently nodular, separated by thin bands of shale and yields, among other fossils, the trilobite *Bumastus barriensis*.

In the northern areas of Wenlock Edge and Buildwas in the Severn Valley its horizon is occupied by the shales of the Buildwas Beds, which succeed the Purple Shales of the Llandovery Series, while in the west at Old Radnor (Fig. 30, p. 57) and Nash Scar near Presteign a massive development of algal (*Solenopora*) limestone is generally considered to be a reef-facies of the Woolhope Limestone (Pl. VIII A). Its abundant fauna, however, shows affinities with that of the Wenlock Shale, which it may, in part, represent.

This reef-facies appears to have been accumulated round the islands of a slowly subsiding archipelago, in lagoons sheltered from the open sea and free from the detrital deposits of rivers.

At Old Radnor a basal conglomerate is present resting on and containing rolled fragments of Longmyndian rocks (Figs. 30 and 31, pp. 57, 59), while near Presteign the limestone rests on the *Pentamerus oblongus* Grits of the Llandovery Series. The slowly subsiding ridge of Longmyndian and Llandovery rocks along the line of the Church Stretton disturbance formed a barrier between the deep waters to the west and north-west and the shallower waters to the east and south-east in which the normal Woolhope Limestone and Wenlock Shale, with their rich brachiopod, crinoid and trilobite faunas, were deposited.

Wenlock Shale.—The Wenlock Shale consists of soft grey shale and calcareous flags in which brachiopods and trilobites are abundant, including *Atrypa reticularis*, *Orthis elegantula*, *Sowerbyella transversalis*, *Dalmanites caudatus*, etc. These shales appear to show very little variation in lithology within the area south-east of the Church Stretton disturbance. The graptolitic facies to the west and north-west of that disturbance is characterized by blue or dark-grey shales, an absence of calcareous beds and a scarcity of shelly fossils.

Wenlock Limestone.—The Wenlock Limestone, which, on account of its resistance to weathering, forms a strong escarpment at its outcrop, as at Wenlock Edge and in the Ludlow, Woolhope and Malvern districts, consists of bluish-grey, thin-bedded, argillaceous limestone bands alternating with thin bands of shale, the whole having an average thickness of about 100 ft. The upper part of the underlying Wenlock Shale is usually full of calcareous nodules, so that the transition upwards into the limestone is gradual. These transitional strata are known as the Tickwood Beds in the Wenlock area. At the top of the limestone there is usually a definite band composed mainly of crinoid remains. The lower part of the overlying Ludlow Shale contains a considerable amount of calcareous matter.

The limestone yields a very rich fauna. Corals, crinoids and stromatoporoids are abundant. There are also many thick-shelled brachiopods, gastropods and large cephalopods. Polyzoa are fairly common, but trilobites are scarce in this area and graptolites are rare or absent.

An important feature is the occurrence of reef-knolls. These are termed 'ballstone' and may occur in any part of the limestone sequence except possibly the top crinoidal bed. They were probably formed as upgrowths of living coral from the sea floor in large branching masses such as can be observed in the Great Barrier Reef of

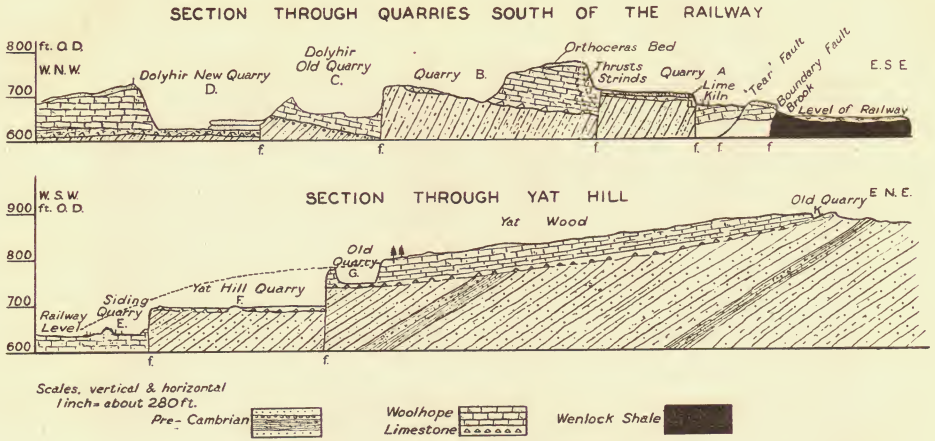


FIG. 31.—*Sections across the Old Radnor District.* (After E. J. Garwood.)

Australia. The intervening stratified limestone and shaly bands would be formed from the deposition of limestone-mud and broken coral detritus between the upgrowing masses of living coral.

The reef masses are mainly composed of large and irregular growths of corals and stromatoporoids and in structure are essentially unstratified, in strong contrast with the adjacent stratified limestone. Bryozoa are common and occasional brachiopods and gastropods occur.

In the Malvern district there is an interesting development of oolitic limestone, while at Woolhope the old quarries at Dormington Wood have long been famous for their rich coral fauna.

The occurrence of graptolites indicative of the Zone of *Monograptus vulgaris* in the 200 ft. of shales below the Wenlock Limestone of Wenlock Edge, and of forms characteristic of the Zone of *Monograptus nilssoni* only 75 ft. above the limestone, has given rise to the suggestion that the limestone may actually lie within the Lower Ludlow Stage as defined for the beds of the graptolite facies farther west; recently, however, *Monograptus vulgaris* has been found above the limestone.

Ludlow Series.—The deposits of the Ludlow Series show a combined shelly and graptolitic facies (Fig. 32, p. 61). They are well exposed in the Ludlow district (Fig. 33, p. 62), where the following succession has been established:—

Upper Ludlow Beds	Ludlow Bone Bed
	Whitcliffe Flags
Aymestry Group	Mocktree or *Dayia* Shales
	Aymestry Limestone
Lower Ludlow Beds.	

The two lower divisions have been further subdivided into a number of zones characterized by the following graptolites in descending order: *Monograptus leintwardinensis*, *M. tumescens*, *M. scanicus*, *M. nilssoni*, *M. vulgaris*. The first does not occur above the Mocktree Shales and the beds assigned to the Zone of *M. vulgaris* may be of Wenlock age, since *Gothograptus nassa*, which usually occurs in that zone, is found below the Wenlock Limestone of Wenlock.

Lower Ludlow.—The Lower Ludlow rocks consist of about 800 ft. of light- to dark-grey shales and mudstones which usually pass up into finely laminated flags with calcareous concretionary bands. Fossils are common, including lamellibranchs, brachiopods, cephalopods and trilobites. At Leintwardine a bed rich in remains of starfish occurs in the upper part of the shales. In the Usk inlier the Lower Ludlow shales are 500 to 600 ft. thick and at Woolhope 525 ft. of beds are assigned to them. Here graptolites indicative of the Zones of *M. tumescens* and *M. scanicus* occur.

Aymestry Group.—The Aymestry Group consists of massive impure dark-blue limestone, usually well bedded and containing in places numerous fossils, and of an overlying series of grey mudstones, the Mocktree Shales, with calcareous concretionary bands showing a tendency to honeycomb weathering. The fossils of the limestone

THE STIPERSTONES AT 'THE ROCK'

A.—WOOLHOPE LIMESTONE, DOLYHIR QUARRIES, OLD RADNOR

B.—WOOLHOPE LIMESTONE, SCUTTERDINE, WOOLHOPE DISTRICT

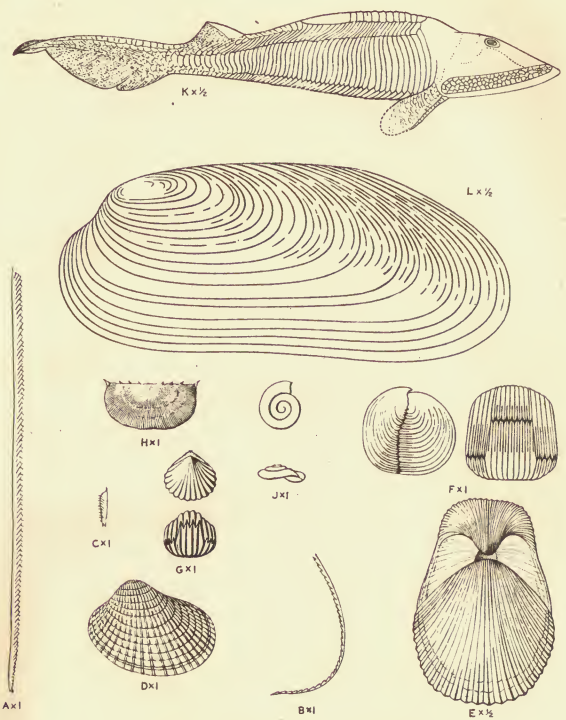


FIG. 32.—*Ludlow, Downtonian and Old Red Sandstone Fossils.*

A. *Monograptus vulgaris* Wood, Lower Ludlow Beds.
B. *Monograptus nilssoni* (Barrande), Lower Ludlow Beds.
C. *Monograptus leintwardinensis* Lapworth, Lower Ludlow Beds.
D. *Cardiola interrupta* J. de C. Sowerby, Lower Ludlow Beds.
E. *Pentamerus* (*Conchidium*) *knighti* J. Sowerby, Aymestry Limestone.
F. *Rhynchonella* (*Wilsonia*) *wilsoni* (J. Sowerby), (two views), Aymestry Limestone.
G. *Rhynchonella* (*Camarotoechia*) *nucula* J. de C. Sowerby (two views), Upper Ludlow Beds.
H. *Chonetes striatellus* (Dalman), Upper Ludlow Beds.
J. *Platyschisma helicites* (J. de C. Sowerby) (two views), Downtonian Beds.
K. Restoration of *Hemicyclaspis murchisoni* (Egerton) after Stensiö, Downtonian Beds.
L. *Archanodon* (*Amnigenia*) *jukesii* (Forbes), Upper Old Red Sandstone.

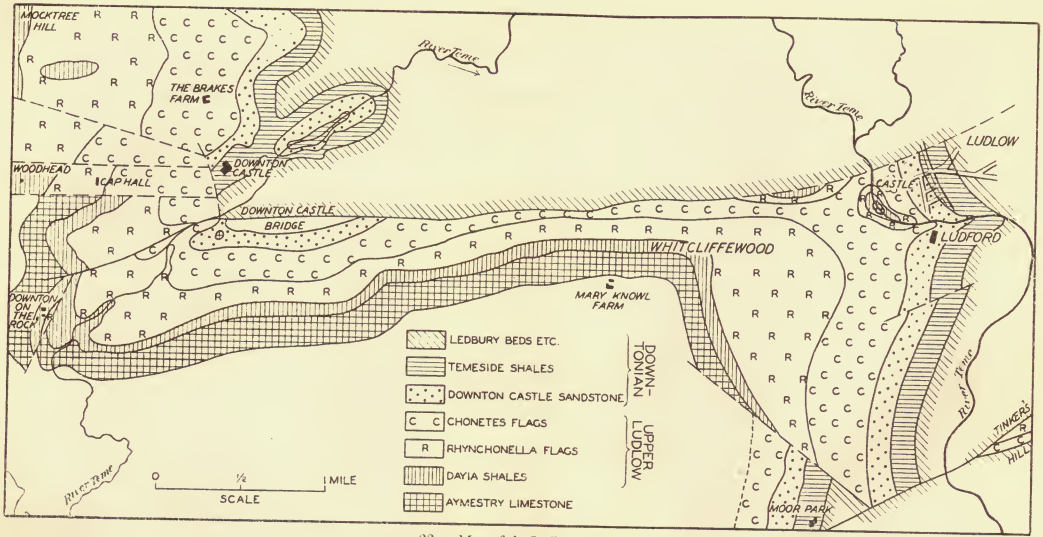


FIG. 33.—*Map of the Ludlow District.*
(After Elles and Slater.)

include the brachiopods *Conchidium knighti*, *Wilsonia wilsoni*, *Leptaena rhomboidalis*, *Strophonella euglypha*, *Atrypa reticularis*, etc., and the graptolite *Monograptus leintwardinensis*. The grey mudstones are frequently characterized by the abundance of the small brachiopod *Dayia navicula*. Both limestone and mudstone vary considerably in thickness. In the Malvern, May Hill, Woolhope and Usk areas the limestone is not so well developed as at Ludlow and the typical fossil *C. knighti* is rare or absent.

Upper Ludlow.—In the Ludlow area the Whitcliffe Flags have been divided into an upper portion with abundant *Chonetes striatellus*, and a lower portion with *Rhynchonella* (*Camarotoechia*) *nucula*, but these divisions may be only of local significance.

The group consists of massive calcareous greenish flags with a fairly rich brachiopod and lamellibranch fauna. A band near the top contains a variety of *Spirifer elevatus* in abundance. These beds are well exposed in the high cliff overlooking the River Teme at Ludlow (Pl. IX A).

In the south-eastern inliers of Woolhope, etc., the Upper Ludlow consists of shales with many calcareous bands, often sandy, and yields *Strophonella euglypha*, *Sieberella galeata* and many other fossils, some of which are characteristic of lower levels, and it is possible that the true Aymestry horizon has been included in these beds.

A westerly thickening of the Upper Ludlow rocks has been observed in the Ludlow district, and this continues into the Clun Forest area.

The highest bed of the Upper Ludlow is the well-known Ludlow Bone Bed, which is composed of a mass of organic fragments cemented by a small amount of calcite. It varies in thickness from an inch or less to a foot or more in various parts of the Welsh Borderland. The organic remains are mainly hard skeletal parts of fishes, crustacea, brachiopods and perhaps annelids. They are now disintegrated, fragmentary and to some extent rolled and worn. The bed also contains occasionally the small spherical fossil *Pachytheca*, which is generally considered to be an alga. The fish are often represented by spines such as *Onchus murchisoni*, while minute tubercles or scales known as *Thelodus parvidens* occur in myriads throughout the rock and in some parts mainly compose its bulk. *Pterygotus*, *Leperditia* and other crustacea occur in small fragments.

In all the areas where the Ludlow Bone Bed has been found, at Wenlock Edge, Ludlow, Malvern, Woolhope, May Hill, etc., there is a very sharp boundary between it and the underlying beds, although in these districts no actual unconformity has been proved at its base.

Downton Series.—The rocks of the Downton Series are divided into the Grey Downtonian or Temeside Group below and the Red Downtonian or Ledbury Group above. The former occurs along the main Silurian outcrop at Wenlock and Ludlow and also at Woolhope and Malvern. The Red Downtonian includes a considerable thickness of the red marls and sandstones originally mapped as the lower part of the Old Red Sandstone (Fig. 34, p. 64).

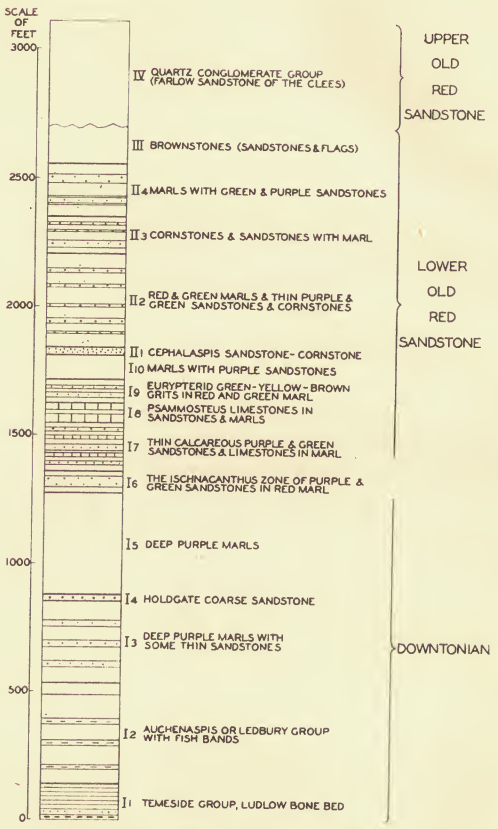


FIG. 34.—*General Succession of the Downtonian and Old Red Sandstone of the Welsh Borderland.*

Grey Downtonian.—In Shropshire this group comprises the Downton Castle Sandstone, with a thickness of about 40 ft., overlain by the Temeside or *Eurypterus* Shales about 115 ft. thick. The sandstone consists of a main massive yellow rock with few fossils and an upper micaceous flaggy portion which, to the south-west, appears to be represented by highly micaceous, greenish, flaggy sandstones known as the Tilestones and formerly worked for roofing slabs. Near the base is a band full of the gastropod *Platyschisma helicites* and the lamellibranch *Modiolopsis complanata*. This is said to pass laterally into a bone-bed, the Downton Bone Bed, with fish remains including *Thelodus parvidens* and the problematical fossil *Pachytheca*.

The Temeside Shales are greenish-grey or olive-coloured shales with thin sandstones and yield small lamellibranchs and *Lingula cornea*. In these beds a grey micaceous grit with fish fragments is known as the Temeside Bone Bed.

The lower beds of the Downtonian are well developed round the Woolhope dome where the Downton Castle Sandstone is represented by coarse, thick-bedded sandstones with carbonaceous inclusions, which appear to be fragments of a plant, *Nematophyton*, associated with *Pachytheca*. These are overlain by greenish mudstones and sandstones full of Eurypterid fragments and the curious fossil *Actinophyllum*.

West of the Ludlow district in the Clun Forest area greenish sandstones and thin-bedded shales occur, and certain beds are crowded with *Platyschisma helicites*, *Modiolopsis complanata* and fish remains. These beds are comparable with the lower part of the Downtonian.

In the Long Mountain the Downton Castle Sandstone is some 50 ft. thick and contains a band, $2\frac{1}{2}$ in. thick, consisting almost entirely of *Platyschisma helicites*. The Temeside Shales are also present, to a thickness of about 100 ft.

Red Downtonian.—In the Wenlock and Ludlow area a fish fauna similar to that of the Grey Downtonian extends up for nearly 2,000 ft. into red strata, including the *Psammosteus* Limestone, originally classed with the Old Red Sandstone.

At Ledbury the Downton Sandstone is succeeded by nearly 300 ft. of red, grey and mottled marls with thin sandstones and bands of grey and purple shale. Numerous fish remains, including the genera *Hemicyclaspis*, *Pteraspis*, *Cephalaspis*, *Auchenaspis*, *Onchus* and *Plectrodus*, have been obtained from these beds together with *Lingula* and *Pterygotus*. A further 350 ft. or so of red and grey sandstones and clays which contain *Lingula cornea* have been included in the Downtonian.

VI. OLD RED SANDSTONE

THE OLD RED SANDSTONE of this district consists of a lower and an upper portion (Fig. 34, p. 64) which are sometimes apparently conformable but have entirely distinct faunas.

On the north-east of the South Wales Coalfield, in Herefordshire and in Shropshire, the Silurian passes up conformably into the Old Red Sandstone with increasing estuarine conditions. Indeed, the Downtonian beds appear to have been deposited on the borders of the main areas of open-sea deposition and mark the transition from the marine conditions of the Silurian to the continental conditions of the Old Red Sandstone which followed the Caledonian uplift (p. 6). During their formation elevation was progressing in the surrounding areas, older rocks were undergoing denudation and the products of erosion were being deposited in a gently subsiding trough.

Lower Old Red Sandstone.—The lower part of the Lower Old Red Sandstone has been termed the Dittonian or the *Pteraspis* Cornstones. It consists of sandstones and cornstones characterized by *Pteraspis rostrata* and other species of the same genus of fish, and *Cephalaspis whitei*. Two species of *Phialaspis*, formerly called *Psammosteus*, have also been recorded. No true marine forms of life occur and *Stylonurus* is absent. *Pteraspis rostrata* does not occur in the underlying Downtonian.

The upper part of the Lower Old Red Sandstone west of Abergavenny has been divided into the Brownstones above and the Senni Beds below, and it is possible that this classification could be extended into the district to the east and north-east. The Brownstones have been recognized at Brown Clee Hill in Shropshire.

The Senni Beds are greenish-brown micaceous flaggy sandstones, shales, marls and thin cornstones. The flags frequently show obscure plant impressions and at Crickhowell have yielded *Pteraspis* (*Rhinopteraspis*) *dunensis* (Roemer).

The Brownstones are apparently unfossiliferous. They were formerly classed with the Upper Old Red Sandstone, but north of the South Wales Coalfield and in Shropshire they are overlain unconformably by undoubted Upper Old Red Sandstone, a fact which suggests that they are of Lower Old Red age.

Upper Old Red Sandstone.—In Shropshire the Upper Old Red Sandstone lies just outside the Welsh Border district. It is represented by the Farlow Sandstones, some 500 ft. thick, which rest transgressively on the Lower Old Red Sandstone. The fauna of the Farlow Sandstones includes *Holoptychius giganteus* and *Sauripterus anglicus* and has nothing in common with the Lower Old Red fauna.

Near Abergavenny the Upper Old Red has yielded *Archanodon jukesii*.

The rocks consist of grey grits and red and yellow sandstones and conglomerates. The pebbles include jasperized rocks indicating desert conditions, and the sand grains are frequently well rounded.

Igneous Intrusions.—Dykes of igneous rock occur in the Red Downtonian and Old Red Sandstone areas at Brockhill on the River Teme north of Shelsley Beauchamp, just beyond the border of the district, at Bartestree north of the Woolhope area, and at Golden Hill between Chepstow and Usk.

The Brockhill Dyke is a compact doleritic rock similar in appearance to the well-known basalt of Clee Hill. The dyke has a width of about 30 ft. and has baked the red marls and sandstones, into which it is intruded, to a depth of 30 ft. on the north side and 17 ft. on the south side.

The Bartestree Dyke is a composite intrusion of doleritic rock containing analcime. It is considered to be of late Carboniferous age. The marls and sandstones are altered in much the same way as at Brockhill.

The Golden Hill intrusion has been described as a monchiquite, the only example known in England and Wales. It is remarkable for its large corroded phenocrysts of augite, biotite and olivine.

VII. CARBONIFEROUS AND PERMIAN

IN THE WELSH BORDER district rocks of Carboniferous age occur in the neighbourhood of Shrewsbury, on and near the Abberley Hills and near Newent in Gloucestershire. With the exception of a small outlier of Carboniferous Limestone that forms Pen-cerig-calch, on the Black Mountains, all Lower Carboniferous rocks may be regarded as lying outside the district. Moreover, the Upper Carboniferous is represented only by Upper Coal Measures.

Permian rocks may possibly be represented by the Haffield Breccia of the Abberley and Malvern Hills.

THE SHREWSBURY COALFIELDS

The pre-Carboniferous rocks of the Welsh Border district form the southern margin of the great synclinal basin of Shropshire and Cheshire. Throughout the greater part of Carboniferous times the southern limit of the area of deposition lay at some unknown position north of the latitude of Shrewsbury; but, later, an extension of the basin took place, with the result that Upper Coal Measures came to overlap the older Carboniferous rocks towards the south. Thus, in the Shrewsbury Coalfields (Fig. 35, p. 68) the Carboniferous Limestone, the Millstone Grit and the Lower and Middle Coal Measures

are entirely wanting, and the Upper Coal Measures rest directly upon pre-Cambrian and Lower Palaeozoic rocks (Fig. 36, p. 69).

Of these coalfields, what may be called the Hanwood Coalfield extends in a curved outcrop from the Breidden Hills to Haughmond

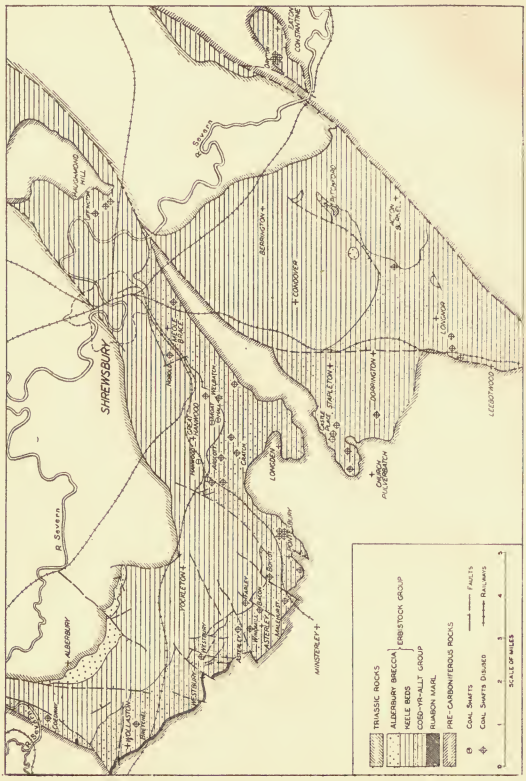
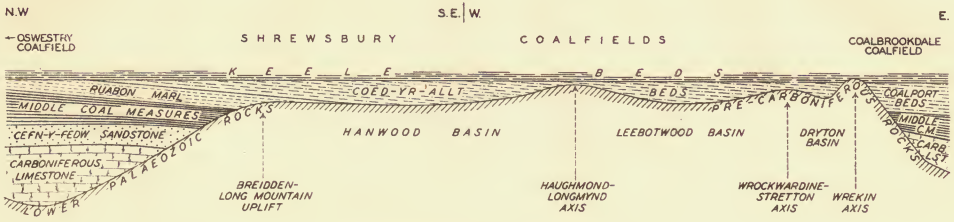


FIG. 35.—*Map of the Shrewsbury Coalfields.*
(The Hanwood, Leebotwood and Dryton Coalfields.)

Hill. That of Leebotwood has been displaced southward along the Church Stretton Fault and a parallel fault to the north-west. In addition, the little outlier of the Dryton Coalfield lies to the east of the main Church Stretton Fault (Fig. 36, p. 69). These coalfields, now structurally separated, were no doubt once continuous. The



HORIZONTAL SCALE QUARTER INCH TO ONE MILE, APPROXIMATELY.
VERTICAL SCALE: ONE INCH TO 2000 FEET, "

FIG. 36.—*Semi-diagrammatic section to illustrate the stratigraphical relation of the Shrewsbury Coalfields to the Oswestry and Coalbrookdale Coalfields.*

sequence of formations in them is similar to that in the Upper Coal Measures of North Wales and Central England.

The Ruabon (Etruria) Marl.—This division is known at outcrop only at the western end of the Hanwood Coalfield, though it may extend, underground, as far east as Great Hanwood. It consists of purple and mottled marls, with some thin bands of impure limestone similar to those that are found in the top of the Ruabon Marl in Denbighshire. The attenuation of the marls in the Hanwood Coalfield is thus due to the absence, through overlap, of the lower beds.

The Coed-yr-Allt (Newcastle-under-Lyme or Halesowen) Group.—This consists of greenish-white sandstones alternating with argillaceous beds that include grey and black shales together with red, purple, green and mottled shales and marls. In this group lie the three workable coal-seams of the area. Of these the lowest, or Thin Coal (1 ft. to 1 ft. 8 in. thick) lies about 30 ft. above the base. The second, or Yard Coal (2½ to 3 ft. thick) lies from 50 to 80 ft. higher; and the highest, or Half Yard Coal (1 ft. 6 in. thick), 60 to 100 ft. above the Yard. There are no working collieries at the present time.

Between the Yard and Half Yard coals a persistent bed of limestone containing the worm-tube *Spirorbis* is found. This bed is usually in two portions, the lower compact, the upper a breccia of limestone fragments in a calcareous matrix. Near Pontesbury the *Spirorbis* limestone attains a thickness of 7 or 8 ft., but elsewhere it is 3 ft. or less in thickness.

Near Pitchford the Coed-yr-Allt Beds have a peculiar basement breccia consisting of chips of Longmyndian shale in a sandy matrix, cemented by black 'bitumen.' From the latter, as related by Murchison, 'Betton's British Oil,' a preparation sold as a medicine, was formerly made.

The Upper Coal Measures (Staffordian) age of the Coed-yr-Allt Group is indicated by fossil plants, which in some beds are abundant, and is confirmed by the non-marine mollusca. Natural exposures in the shales are rare. Stream sections in Braggington Wood have yielded plant remains and freshwater molluscs; but old mine spoil-heaps provide the readiest source of fossils. An interesting fossil that has been found in the Coal Measures of the Dryton Field is *Prestwichianella rotundata* (Prestwich), an arachnid allied to the king-crab (*Limulus*).

The Erbistock Group.—This group consists of the Keele Beds and the Alberbury Breccia. The Keele Beds are red marls and sandstones with pellety, calcareous lenticles. A limestone containing *Spirorbis* occurs, near the base, in the Leebotwood Coalfield.

The Alberbury Breccia is made up of large and small sub-angular fragments of Carboniferous Limestone (some of them dolomitized) with some of purple sandstone, and rounded quartz pebbles, in a calcareous matrix. The breccia is interbedded with red marl. A good exposure is afforded by a roadside quarry at Cardeston. The Alberbury Breccia is probably approximately equivalent to the Calcareous Conglomerate (Bowhills) Group of Central England; but the material of the former was almost certainly derived from the

north-west, probably from the neighbourhood of Llanymynech, where the Carboniferous Limestone is well developed.

COAL MEASURES OF THE ABBERLEY HILLS.

A narrow southward prolongation of the Forest of Wyre Coalfield lies to the west of the northern end of the Abberley Hills. The beds in it appear to be all of Upper Coal Measures age. The Wyre Forest Coalfield, as a whole, is best considered in conjunction with those of Central England.

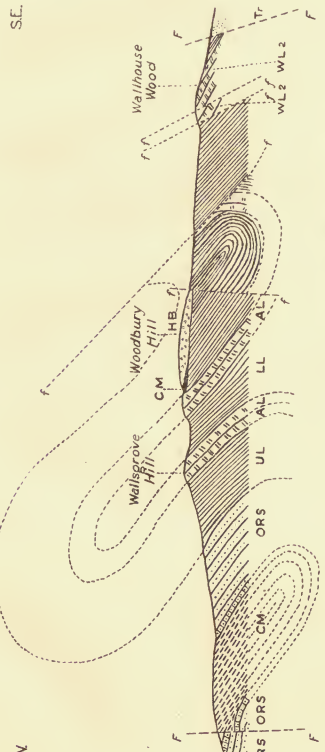


FIG. 37.—*Section across Woodbury and Wallsgrove Hills, and the adjacent portion of the Wyre Forest Coalfield.* (After T. T. Groom.)

Tr = Trias.
HB = Haffield Breccia.
CM = Coal Measures.
ORS = Old Red Sandstone and Passage Beds.
UL = Upper Ludlow.
AL = Aymestry Limestone.
LL = Lower Ludlow.
WL_2 = Wenlock Limestone.
FF = Faults.
ff = Hypothetical faults.

On the Abberley Hills small outcrops of Coal Measures occur on Woodbury Hill, Berrow Hill and at a position about one and a quarter miles north-north-east of the northern end of the Malvern range. In the last mentioned locality and on Woodbury Hill these rest upon Silurian rocks; on Berrow Hill their substratum is ' Old Red Sandstone.' On Woodbury and Berrow Hills they are overlain by the Haffield Breccia (*see* below). These Coal Measures appear to be of later date than those of the adjacent portion of the Wyre Forest Coalfield, for they seem to be unaffected by the movements that have folded and even overturned those measures, together with the Old Red Sandstone and Silurian rocks (Fig. 37, p. 71). The structure of the Malverns has recently been discussed by N. L. Falcon (1947), with sections across Walsgrove and Woodbury hills to illustrate his views.

THE NEWENT COALFIELD

Coal Measures emerge in a narrow outcrop between the Triassic rocks and the Old Red Sandstone at intervals from the Ledbury Silurian area to May Hill. They consist of grey and reddish clays and sandstones with coal seams that, according to Murchison, were formerly worked opencast. The beds have yielded plants that show their Upper Coal Measures age. The Coal Measures presumably extend eastward under the Triassic rocks, and the occurrence of a sulphurous spring east of Newent was attributed by Murchison to the presence of buried Coal Measures in that locality.

THE HAFFIELD BRECCIA OF ABBERLEY AND MALVERN

This is a stratified deposit which rests unconformably upon Coal Measures, Lower Palaeozoic and pre-Cambrian rocks in the Abberley and Malvern Hills. It consists of sub-angular fragments, up to 2 ft. in length, of various rocks, including sandstone from the Old Red and Silurian limestone and shale. Its age, whether Upper Coal Measures or Permian, is uncertain. Probably it is approximately equivalent to the Clent Breccia of Central England, but presents certain points of difference, which may, however, be explicable by a difference in the source of the component materials. Like the Clent Breccia, it is probably the product of the denudation of upland regions under desert conditions.

VIII. TRIASSIC AND LATER SYSTEMS

TRIASSIC ROCKS FRINGE the Welsh Border district on the north and east, though in the north they are very largely concealed by Glacial and other superficial deposits. All the divisions up to and including the Keuper Marl are represented.

Bunter.—Of the three divisions of the Bunter Series, the Lower Mottled Sandstone is a non-pebbly sandstone, brick-red in colour, with greenish blotches. It is usually highly false-bedded, and the steep inclination of the laminae, together with the rounded character of the grains, suggests that it originated as a wind-borne deposit. The Lower Mottled Sandstone is absent in the south, near the Abberley and Malvern Hills.

The Bunter Pebble Beds consist of sandstones of more angular grain, with pebbly sandstones and conglomerates. In the north the conglomerates contain pebbles of rocks resembling Uriconian rhyolites and tuffs, in addition to the usual quartzites.

The Upper Mottled Sandstone differs little from the Lower Mottled Sandstone. In the north it is non-pebbly, but in the south, near Abberley, it contains bands of sub-angular fragments of purple grit, quartzite and other rocks.

Keuper.—The Keuper Series can be considered to enter the district only in the south. The Lower Keuper Sandstone consists of sandstones generally coarser and more angular in grain than those of the Upper and Lower Mottled Sandstones, and of a less bright red colour. Its basement bed is a breccia or conglomerate, and lenticles of calcareous breccia ('catbrain') occur well above the base. The basal breccia is especially thick and prominent near Abberley Hill, where it is not unlike the Haffield Breccia and may be in part derived from it.

The Keuper Marl consists of red and purple marls with greenish streaks, and thin arenaceous beds known as 'skerries.' It is brought against the older rocks of the Abberley and Malvern Hills, on the east side, by the Malvern Fault (but see Falcon 1947).

In this southern area overlap takes place amongst the Triassic rocks towards the south and west. At Knightwick the Upper Mottled Sandstone rests directly upon the Haffield Breccia; and it probably forms the base of the Trias alongside the greater part of the Abberley and Malvern Hills. South of Bromsberrow, to the west of the Malvern Fault, the Keuper Sandstone rests upon Coal Measures and Old Red Sandstone, as it does also in the Newent Coalfield.

Ancient and Modern Physiography.—Many of the main physical features of the Welsh Border district probably came into

existence as the result of pre-Triassic movements, and it was probably one of high elevation and relief in Triassic times. It is unlikely, therefore, that the Triassic deposits extended over the district much beyond their present limits. Owing to sinking and denudation the successive members of the system spread progressively farther, and the Keuper Marl had the widest extension. It seems possible, moreover, that the Longmynd may have been covered by some part of the Triassic sandstones, and that these, which in places contain barytes as nodules or cementing material, may have been the proximate source of that mineral in the veins of the Longmyndian rocks.

Apart from superficial deposits and a small patch of Lower Lias capping Berrow Hill three miles east of Bromsberrow, no formations later than the Keuper Marl occur in the Welsh Border district, and its history in the remainder of the Secondary and the Tertiary eras can only be inferred from indirect evidence.

The main outcrops of the Rhaetic and Lias formations approach within a few miles of the borders of the district in the south, and an outlier of them lies, at Prees, only some eight miles to the north. It is probable that the seas in which these formations were deposited submerged part of the district; but they would not appear to have spread much beyond the area that had been occupied by the lake in which the Keuper Marl was formed. The sea appears to have extended farther into the district in Middle Jurassic times, and perhaps submerged the whole of it; but in Upper Jurassic times it receded, and the whole district may have become dry land again.

In the early part of the Cretaceous period the district was included in an extensive land area; but, with the Upper Cretaceous, it became submerged again, and probably was entirely covered by the sea in which the Chalk was deposited.

The post-Cretaceous movements elevated the district above sea-level once more, and as a whole it may never since have been submerged. The present river system was perhaps initiated upon a surface of slightly flexured Chalk. The removal of the Cretaceous and Jurassic deposits, however, by laying bare the uneven surface of the older rocks caused such profound modifications of the drainage system that only slight suggestions of its original condition remain.

IX.—GLACIAL AND OTHER SUPERFICIAL DEPOSITS

Glacial.—During the Pleistocene Glacial Period ice-sheets from three sources entered the Welsh Border district. The northern part was invaded by ice from the north which brought boulders of granite and other rocks from the south-west of Scotland and the Lake District, and shells from the bed of the Irish Sea. Ice also entered from the north-west, bringing fragments of volcanic rock and of Lower Palaeozoic sediments from North Wales. The third ice-sheet moved eastward and north-eastward from Central Wales, and its maximum extension was probably later than that of the Irish Sea and North Welsh Ice-sheets. The advance and subsequent retreat of all these ice-sheets, notwithstanding minor oscillations, constitute a single major glacial episode; and the deposits left by them belong to the 'Newer Drift.' Only doubtful traces of an older drift have been found in the district.

The combined Irish Sea and North Welsh Ice-sheets extended, at their maximum, as far south as a sinuous line from Wenlock Edge to the Breidden Hills. The Central Welsh Ice-sheet reached an irregular line from the south-west end of the Long Mountain to a little west of Bromyard. The Black Mountains, which nourished a small ice-cap of their own, protected the area south of Hereford; but the Central Welsh ice sent a lobe down the valley of the Usk about as far south as the site of the town of that name (Fig. 38, p. 77).

As the ice-sheets retreated they left their load of debris as mounds or formless spreads of stony clay; whilst kettle-moraines resulted, perhaps, from the melting of stagnant lobes or detached masses of ice. Wherever the ice-front remained stationary for any considerable period, the water issuing from it deposited sand and gravel as kames, or, in glacial lakes, as deltas.

The glacial deposits are thickest and most continuous in the northern part of the district, where, in many places, they effectually mask the pre-glacial topography. Though in places of considerable thickness, they are very irregularly distributed, and it is probable that the pre-Glacial surface had a more accentuated relief than that of the present day.

The boulder-clay deposited by the Irish Sea ice is commonly reddish in colour and, in many places, sandy. That from the Welsh ice is generally brown; but where the ice passed over red rocks, such as the Keele Beds, it is red. Boulders of granite and other rocks from Scotland and the Lake District have been left at a height of 800 ft. above sea-level on Wenlock Edge, and at over 1,000 ft. near Woolstaston and Pulverbatch; whilst boulders of Stiperstones quartzite lie at over 1,300 ft. on Wilderley Hill near Smethcott. Glacial striae have

been noted on Charlton Hill and on Sharpstone Hill, indicating ice-movements from north-north-west to south-south-east and from north to south respectively.

Glacial sand and gravel occupy considerable areas, and are most extensive on the lower ground. Two long ridges of sand and gravel near Stapleton and Dorrington present somewhat the appearance of eskers, that is, of deposits from an englacial stream issuing from a retreating ice-front. They do not, however, show the critical characters of such deposits, and are, perhaps, the remains of a once continuous spread that formed, with the sands and gravels of Bomere, part of a large kettle-moraine.

The sands and gravels of Buildwas and Strethill contain marine shells probably derived from the bed of the Irish Sea. They are, in places, overlain by boulder-clay, which also contains marine shells and fossils derived from the Silurian and Carboniferous rocks.

In the central and southern parts of the district the drift deposits are less continuous. The valley to the south of the Shelve hills, and its continuation eastward to Plowden, is covered with deposits that are probably of lacustrine or outwash origin; with some moraine-like mounds, near Plowden, containing fragments of Longmyndian and Uriconian rocks and of Stiperstones quartzite.

The movement of the ice in the southern part of the district was, in detail, somewhat complex. The high ground in the west of the district tended to deflect the ice coming from Central Wales. The upper parts of the Clun and Teme valleys contain drift of local origin only; but the Welsh ice escaped north-eastward, over the col on which the sources of the River Clun and River Mule now lie, into the valleys of the Mule and Caebitra. It reached a height of at least 1,750 ft. above Ordnance Datum on Radnor Forest, and left boulders of dolerite like that of Baxters Bank, nine miles to the north-west, at a height of 1,400 ft. on the slopes of Bryn-y-Main. In places it escaped eastward, through the valley of the River Lugg, to the north of Radnor Forest, and over cols in the high ground farther south. In general, however, the ice-stream was deflected southward and south-eastward to reinforce the great glaciers of the Wye and Usk valleys (Fig. 38, p. 77).

The Wye glacier, emerging from the narrow valley to the north-west of the Black Mountains, and augmented by ice passing over cols in the high ground to the west, spread out in a great lobe over the Herefordshire lowland (Fig. 38, p. 77). This lobe, with the masses or morainic and outwash drift that it left banked against the hills from Kington to Orelton, exercised a great influence upon the drainage of the area. Boulders recognizable as from Hanter Hill and Stanner Rocks were carried as far east as Cricks Green, three miles south-south-west of Bromyard. During its retreat the ice of the Wye glacier left terminal moraines across the valley in places above Hereford. An interesting deposit in the valley of the Wye at Bredwardine and Breinton is a grey clay containing foraminifera. It appears to be older than at least part of the Glacial deposits, and presumably indicates an inlet of the sea at some time before the maximum extension of the ice.

A.—UPPER LUDLOW BEDS AT THE WHITCLIFFE, LUDLOW

B.—LUDLOW CASTLE AND THE RIVER TEME

A.—HANTER HILL, WORSEL WOOD AND STANNER ROCKS

B.—THE BLACK MOUNTAINS, ABERGAVENNY

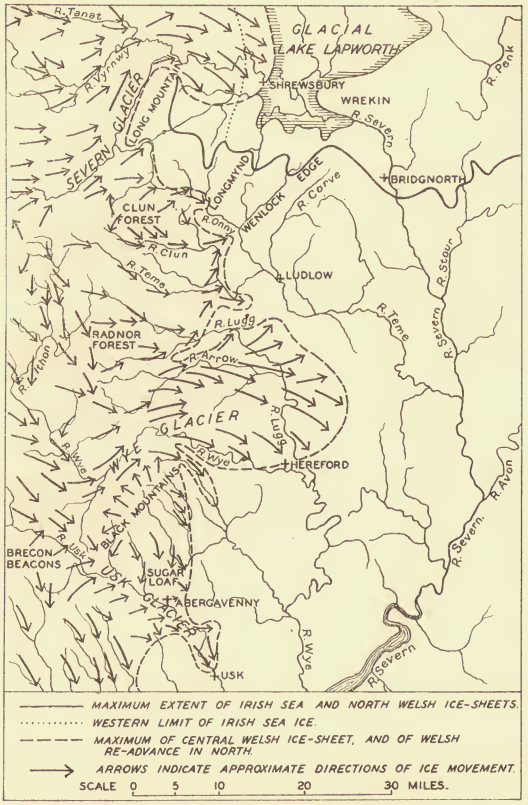


FIG. 38.—*Map to illustrate extent of ice-sheets in the Welsh Border district.* (Based, in part, upon Dwerryhouse and Miller.)

The Wye glacier did not override the Black Mountains, the valleys of which contain only boulders of local origin.

The Usk glacier has left morainic deposits and outwash gravels over a considerable area near Abergavenny.

Glacial Lakes.—The advance of ice into the Welsh Border district impounded water against the high ground as lakes, and with the retreat of the ice such lakes again came into existence. A lobe of the combined Irish Sea and North Welsh Ice-sheets extended into the vale of Church Stretton, where it may have held up a lake against the watershed in that valley, which probably then lay near Marshbrook, about two and a half to three miles south of its present position (Fig. 39, p. 79). Water flowing from the lake, or perhaps directly from the ice, carried pebbles of northern granite and of Breidden dolerite to the neighbourhood of Bromfield, Ludlow and Wooferton, where they are found in gravels that now form a terrace in the valley of the River Teme. As this ice-lobe melted away and its surface became reduced in height below that of the watershed then established in the Stretton-Marshbrook gap, the tendency would be for the water to escape northward, or north-eastward, over or around the ice, and any glacial lake in the Cound Brook Valley would have become merged with one of those described in the next paragraph.

In pre-Glacial times a continuous watershed probably extended across the site of the present Severn Valley near Ironbridge. The area to the north-west of this watershed drained northward to the Irish Sea. With the advance of the ice-sheet from the north lakes were impounded against this watershed in the Buildwas and Coalbrookdale area. The overflow from one of these, occupying Coalbrookdale, into the head of a tributary of the River Stour, probably initiated the Ironbridge gorge. With a retreat of the ice-front and a lowering of the level of overflow, the Coalbrookdale lake became merged with a larger one covering the site of Buildwas. The further retreat of the ice-sheet united this lake with a great spread of water, the margin of which is roughly represented by the present 300-ft. contour line. To this the name 'Glacier Lake Lapworth' has been given, in honour of the geologist by whom this explanation of the origin of the Ironbridge gorge was first suggested.

With the retreat of the ice-sheets from the high ground to the north of the Longmynd, torrents of water, produced probably by melting snows, swept coarse gravels down the valleys and deposited them in the margin of this lake. The overflow from Glacier Lake Lapworth eventually eroded through the barrier at Ironbridge; the lake was drained, and the present course of the Severn established.

At about the same time, or shortly before, a re-advance of ice from Wales took place, extending, perhaps, as far east as the site of Shrewsbury, and brown 'Welsh' boulder-clay was deposited upon the outwash sands and gravels of the Irish Sea Ice-sheet and upon the coarse gravels brought down by torrents from the hills.

Changes of Drainage.—In pre-Glacial times streams represented by the upper parts of the West and East Onny Rivers appear to have flowed southward, across the Lydham Valley, to join the River Clun, through valleys that can still be traced. Ice from Clun Forest and that from Central Wales which crossed the col at the head of the River Mule appear to have blocked these valleys and diverted the streams eastward to form the Plowden gorge, which they eroded to a depth

sufficient to retain the drainage after the ice had retreated. At a stage later than this diversion a lake was perhaps formed in the upper part of the Camlad Valley, impounded by the Severn glacier, which abutted upon the western slopes of the Shelve hills. The overflow from this lake, escaping northward, between the ice and the high ground, excavated the gorge known as Marrington Dingle. At the northern end of the gorge, owing to the presence of the Severn glacier,

FIG. 39.—*Contoured map of the central part of the Welsh Border district. To illustrate glacial changes of drainage.*

(Based mainly on Dwerryhouse and Miller.)

Arrows indicate pre-glacial directions of drainage.

the water could only escape north-eastward, through the Marton Valley, between the Long Mountain and the Shelve hills. Escape in this direction could only have been possible if there was an outlet at a sufficiently low level, which suggests that the Irish Sea Ice-sheet had already retired from the Shrewsbury lowland far enough to allow Glacier Lake Lapworth, at a level of about 300 ft., to come into existence. This would place the maximum of the Central Welsh ice later than that of the Irish Sea ice, and probably at about the same time as that of the re-advance of Welsh ice into the Shrewsbury area already mentioned.

The present course of the River Teme is largely the result of glacial diversions (Fig. 39, p. 79). Its original course was probably southward from Leintwardine to Aymestry. The advance of the great Wye glacier blocked a series of gaps in the hills between Kington and Aymestry through which independent streams had flowed, diverting these streams east-north-eastward and uniting them to form the present course of the River Lugg. The gap at Mortimers Cross, one mile south of Aymestry, was also blocked, by ice that extended north of the latter place and held up a lake in the Vale of Wigmore in which a delta was formed of gravel washed out from the ice-front. The water of the lake overflowed near Burrington and carved out the gorge between that place and Downton Castle, in which the River Teme now flows.

Again, that part of the Teme Valley in which Tenbury lies was probably occupied, before the advance of the ice, by a river that flowed westward to join another flowing southward from Ludlow to Leominster, and then, perhaps, south-westward to the River Wye. The advance of the ice, and the formation of a moraine at Orleton, blocked the outlet to the south and diverted the Teme drainage to its present eastward direction.

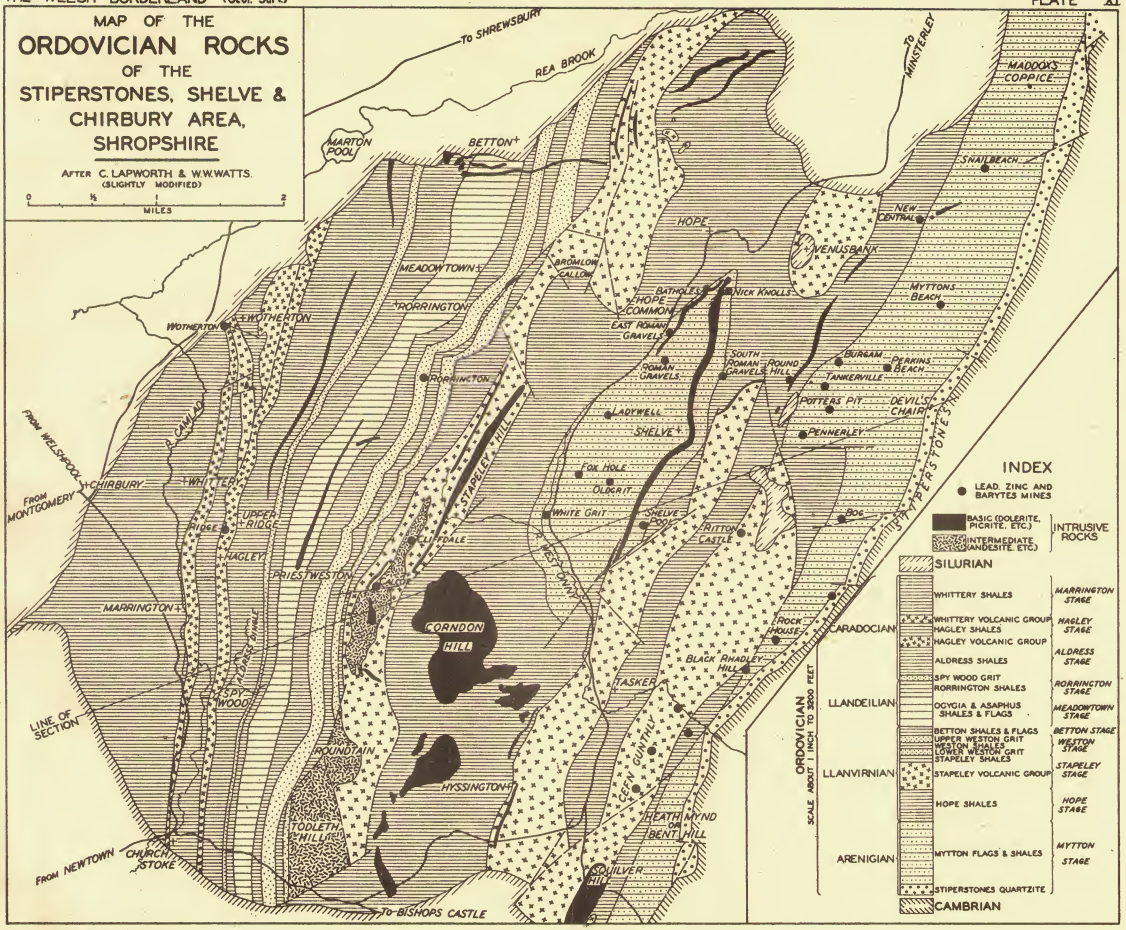
Post-Glacial.—Of the post-Glacial deposits the most noteworthy are the gravels that form terraces in many of the river valleys. In some of these gravels bones and teeth of animals such as deer, horse, rhinoceros and hyaena have been found. Some of the earlier terraces are hardly post-Glacial, as the district had not become entirely free from ice when they were formed.

In the valley of the River Severn, above Ironbridge three terraces, at successively higher levels, can be distinguished. The highest (and oldest) of them, though it extends for some distance up the Rea Brook, cannot be traced above Shrewsbury in the Severn Valley. Its absence there is perhaps due to the continued presence, at the time of its formation, of the ice of the Welsh re-advance.

Other rivers have important terraces. That of the River Teme, near Ludlow, in which pebbles of northern rocks occur, has already been mentioned. Of the gravels of the River Wye, some of those near Hereford may be older than the local glaciation; and there are traces of others, still older, at a higher level.

Most of the larger rivers have formed broad alluvial flats. The winding course of the River Severn above Buildwas, apart from meanders confined within the alluvial flat, may be due to the irregular drift-covered surface upon which the river was left to wander after the draining of Glacier Lake Lapworth. The curious bend at Shrewsbury, where, near the Quarry, the river has cut down to the solid rocks (Keele Beds), may have arisen thus.

A superficial deposit that deserves special mention is the great mass of calcareous tufa, or travertine, one of the largest in the country, that forms the Southstone Rock on the south-west side of the Teme Valley, near Shelsley Walsh. This is a stalagmitic or spongy deposit from the waters of a spring issuing from calcareous beds in the Old Red Sandstone.



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